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U.S. Army Environmental Center

**FORT DEVENS
FEASIBILITY STUDY
FOR GROUP 1A SITES**

FINAL
REMEDIAL INVESTIGATION ADDENDUM REPORT
DATA ITEM A009

**VOLUME I OF IV
REPORT TEXT**

CONTRACT DAAA15-91-D-0008

**U.S. ARMY ENVIRONMENTAL CENTER
ABERDEEN PROVING GROUND, MARYLAND**

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The U.S. Army Environmental Center (USAEC) directed ABB Environmental Services, Inc. (ABB-ES), under Contract No. DAAA15-91-D-0008, to collect environmental samples at Fort Devens, Massachusetts to fill data gaps identified during initiation of the Feasibility Study (FS) for Group 1A sites. The Group 1A sites include the Shepley's Hill Landfill and Cold Spring Brook Landfill at Fort Devens. This Remedial Investigation (RI) Addendum report summarizes the supplemental field investigations, presents the data obtained, and updates the baseline risk assessment prepared for the RI report.

Field investigation programs were conducted between September 1992 and July 1993 and included collecting and analyzing of sediment core samples from Plow Shop and Cold Spring Brook ponds, collecting and analyzing fish tissue samples from these two ponds, and conducting a macroinvertebrate study of the two ponds. In addition, several new monitoring wells were installed and groundwater samples were collected for analysis from 27 monitoring wells at Shepley's Hill Landfill and from 10 monitoring wells at Cold Spring Brook Landfill. Soil, sediment, and groundwater samples were also collected from several other areas, including Nonacoicus Brook Wetland and Grove Pond adjacent to Shepley's Hill Landfill, and the Magazine Area adjacent to Cold Spring Brook Landfill.

The analytical data confirm that there are widespread elevated concentrations of several inorganics in Plow Shop Pond sediments including arsenic, barium chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. Of these, Shepley's Hill Landfill is interpreted to be the major contributor of iron, manganese, barium, and nickel. Shepley's Hill Landfill is also a source of arsenic contamination. Inflow from Grove Pond is interpreted as the major source of arsenic, copper, chromium, lead, mercury, and zinc.

Risk calculations made during the human health risk evaluation for Shepley's Hill Landfill suggest that a recreational fisherman or family member who consumes fish from Plow Shop Pond may experience cancer risks of $3x10^{-6}$ to $4x10^{-4}$, due primarily to arsenic, and noncancer risks (hazard quotients [HQs] range from 2 to 7) due primarily to mercury. Direct contact with sediment by adolescents was estimated to present cancer risks of $2x10^{-5}$ to $6x10^{-4}$, due primarily to arsenic. Because the calculations may overestimate risk as a result of uncertainty associated with arsenic, the application of a downward modifying factor of 10 may be appropriate.

Application of the risk modification factor for arsenic results in cancer risks that are within the Superfund target risk range of $1x10^{-6}$ to $1x10^{-4}$, and the conclusion that the major health risk associated with Plow Shop Pond sediment and fish is attributable to mercury, a contaminant not attributed to Shepley's Hill Landfill. Concentrations of mercury in bullhead and bass fillets exceed the U.S. Food and Drug Administration action level of 1 ppm.

The human health risk evaluation indicates that two organic analytes in groundwater, 1,2-dichloroethane and dichlorobenzenes present cancer risks of $6x10^{-6}$ and $3x10^{-6}$, respectively, that are within the Superfund target risk range. Arsenic in groundwater presents a cancer risk range (unmodified to account for uncertainty associated with arsenic) of $8x10^{-5}$ to $2x10^{-3}$. Application of the modifying risk factor results in a risk range due to arsenic of $8x10^{-6}$ to $2x10^{-4}$. Hazard quotients for manganese and arsenic both exceeded one.

The ecological risk assessment suggests that sediments in Plow Shop Pond may pose a risk to aquatic and semiaquatic receptors. The primary ecological risk contributor is mercury, followed by chromium, arsenic, and manganese.

The human health risk evaluation for Cold Spring Brook Landfill indicates that risks to a recreational fisherman or family member who consumes fish caught in Cold Spring Brook Pond fall within the Superfund target risk range. The risks associated with direct sediment contact are also within the Superfund target risk range.

The risks associated with surface soil contact range from below the Superfund target risk range under current exposure scenarios to $4x10^{-5}$, within the target risk range, under assumed future conditions.

Risk calculations made during the risk evaluation suggest that arsenic in unfiltered groundwater and bis(2-ethylhexyl)phthalate present cancer risks exceeding the U.S. Environmental Protection Agency point of departure. In addition, the HQ for manganese ranged from 4 to 10. The calculations may overestimate risks for each of these chemicals. In the case of arsenic, calculations based on filtered groundwater data or after application of a downward modifying factor of 10 result in estimated cancer risks within or below the target risk range. The primary Maximum Contaminant Level (MCL) for bis(2-ethylhexyl)phthalate of 6 μg/L was exceeded only by its maximum detected concentration of 14 μg/L; the average

concentration of 4 μg/L was below the MCL. In addition, this compound is expected to sorb to particulate matter and not to be in a dissolved, mobile state. Finally, noncancer risks associated with manganese in drinking water may be overestimated. Consideration of these factors leads to the conclusion that exposure to groundwater downgradient of Cold Spring Brook Landfill will not result in unacceptable risk.

The ecological risk assessment suggests that contaminants of potential concern at Cold Spring Brook Pond are not resulting in adverse ecological risks to semiaquatic receptors. Although low levels of risks are predicted, it is unlikely that these risks are present throughout the pond. Limited evidence exists indicating that low levels of risk to aquatic receptors may occur in portions of the pond directly adjacent to the landfill.

The available data do not indicate that Cold Spring Brook Landfill is affecting water quality at Patton Well located about 600 feet west of the landfill.

Public health and ecological Preliminary Risk Evaluations conducted for detected contaminants indicate some exceedances of public health standards or guidelines for soil and groundwater and one exceedance of an ecological Protective Contaminant Level. However, the exceedances are based on comparisons to conservative standards and are not considered to represent significant public health or ecological risk.

Concentrations of polynuclear aromatic hydrocarbons and inorganics measured in soil samples collected within the Magazine Area were below reportable concentrations listed in the Massachusetts Contingency Plan. Available data do not suggest that the Magazine Area is a source of downstream contamination.

Recommendations

Based on the results and interpretation of the supplemental RI and the updated baseline risk assessment, ABB-ES recommends the following actions:

- Perform a FS to evaluate alternatives to reduce potential human health risks associated with potential future exposure to groundwater at Shepley's Hill Landfill.

- Perform a FS to evaluate alternatives to reduce potential ecological risks associated with exposure to sediment hotspots at Cold Spring Brook Landfill.

- Perform a separate FS to evaluate alternatives to reduce potential human health and ecological risks associated with exposure to contaminated fish and sediments in Plow Shop Pond. This FS would be performed following resolution of issues concerning contaminant distribution and concentrations in Grove Pond, and the potential for Grove Pond to be a continuing source of contamination to Plow Shop Pond.

1.0 INTRODUCTION

ABB Environmental Services, Inc. (ABB-ES) prepared this Remedial Investigation Addendum Report in accordance with the U.S. Army Environmental Center (USAEC; formerly U.S. Army Toxic and Hazardous Materials Agency [USATHAMA]) Contract DAAA15-91-D-0008, Delivery Order 0004. This report summarizes supplemental remedial investigation (RI) activities at the Group 1A sites at Fort Devens, Massachusetts, and interprets investigation results. The Group 1A sites were identified for investigation in the Fort Devens Master Environmental Plan (MEP) and are subject to a Federal Facility Agreement (Interagency Agreement [IAG]) between the U.S. Department of the Army and the U.S. Environmental Protection Agency (USEPA). Fort Devens was placed on the National Priorities List (NPL), effective December 21, 1989. The Group 1A sites consist of the sanitary landfill incinerator, Area of Contamination (AOC) 4; sanitary landfill No. 1 or Shepley's Hill Landfill, AOC 5; the asbestos cell, AOC 18; and Cold Spring Brook Landfill, AOC 40. Figure 1-1 shows a site location map for the Group 1A sites.

On September 21, 1990, USAEC assigned a delivery order to Ecology and Environment, Inc. (E&E) under Contract DAAA15-90-D-0012, to conduct RIs at Shepley's Hill Landfill and Cold Spring Brook Landfill. Previous investigations at both landfills indicated the need for further characterization. The RIs for the Shepley's Hill and Cold Spring Brook landfills were designed to compile data needed to assess the type and location of hazardous materials at the landfills and the impact from these materials on the surrounding environment.

During initiation of the Feasibility Study (FS) to evaluate alternatives to remediate contamination at the Group 1A sites, the U.S. Army identified several data gaps in the draft RI report that affected preliminary technology screening and the development of remedial alternatives (E&E, 1993). As a result, supplemental field investigations were conducted to better establish the nature and extent of contamination at the Shepley's Hill and Cold Spring Brook landfills to support engineering evaluations and enable completion of the FS. Activities to fill data gaps included installation of additional groundwater monitoring wells; collection and analysis of groundwater, surface water, soil, and pond sediment samples; pond macroinvertebrate studies; and studies of contaminant bioaccumulation in fish tissue.

Supplemental field investigations included the collection of one sediment and three soil samples from the area of the former railroad roundhouse. Because the railroad roundhouse is not part of the Group 1A sites, the results of that sampling will be presented in a separate report.

1.1 Purpose and Organization of Report

The purpose of this report is to describe data gap activities, present newly acquired data, and update the baseline risk assessment. The RI Addendum report consists of eight sections. Section 1.0 provides a brief description and history of the Shepley's Hill and Cold Spring Brook landfills. In addition, it introduces information about adjacent sites that may have contributed contamination to the AOCs.

Section 2.0 describes Data Gap activities that comprised the field investigation program at Shepley's Hill and Cold Spring Brook landfills.

Section 3.0 describes physical characteristics at Shepley's Hill and Cold Spring Brook landfills.

Section 4.0 discusses the nature and extent of contamination at the two landfills, based on data collected during the supplemental field investigation.

Section 5.0 discusses the fate and transport of contaminants in sampled media.

Section 6.0 presents a human health risk assessment and Section 7.0 presents an ecological risk assessment (ERA).

Section 8.0 presents conclusions and recommendations based on information gathered during the supplemental remedial investigation.

1.2 DESCRIPTION OF AOCs

1.2.1 Shepley's Hill Landfill

Shepley's Hill Landfill encompasses approximately 84 acres in the northeast corner of the Main Post at Fort Devens. It is situated between the bedrock outcrop of Shepley's Hill on the west and Plow Shop Pond on the east (Figure 1-2). Nonacoicus Brook, which drains Plow Shop Pond, flows through a wooded wetland at the north end of the landfill. The southern end of the landfill borders the Defense Reutilization and Marketing Office (DRMO) yard and a warehouse area. An area east of the landfill and south of Plow Shop Pond is the site of a former railroad roundhouse.

Shepley's Hill Landfill includes three AOCs: AOC 4, the sanitary landfill incinerator; AOC 5, sanitary landfill No. 1 or Shepley's Hill Landfill; and AOC 18, the asbestos cell. The sanitary landfill incinerator was located in former Building 38 near Cook Street within the area included in Phase 1 of the sanitary landfill closure. The incinerator was constructed in 1941, and burned household refuse and operated until the late 1940s. Ash from the incinerator was buried in the landfill. The incinerator was demolished and buried in the landfill in September 1967. The building foundation was removed and buried on site in 1976.

Review of the surficial geology map of the Ayer Quadrangle (Jahns, 1953) shows that, in the early 1940s, the active portion of the landfill consisted of approximately 5 acres near the end of Cook Street, near where monitoring well SHL-1 is located. The fill was elongated north-south along a preexisting small valley marked by at least two swamps (probably kettle holes) and lying between the bedrock outcrop of Shepley's Hill to the west and a flat-topped kame terrace with an elevation of approximately 250 feet to the east, adjacent to Plow Shop Pond (E&E, 1993). During the landfilling operation, the valley was obliterated, as was much of the kame terrace, which may have been used as cover material. Background information indicates the landfill formerly operated as an open burning site.

During its last few years of use, the landfill received about 6,500 tons per year of household and military refuse, and operated using the modified trench method. There is evidence that trenches in the northwest portion cut into previously used

areas containing glass and spent shell casings. The glass dated from the mid-nineteenth century to as late as the 1920s. The total depth of the refuse is about 30 feet (DEH, 1985a).

In an effort to mitigate the potential for off-site contaminant migration, Fort Devens initiated the Fort Devens Sanitary Landfill Closure Plan in 1984, in accordance with Massachusetts regulations 310 CMR 19.000. The plan, written by Gale Engineering, was approved by the Massachusetts Department of Environmental Protection (MADEP) in 1985 and contained the following four stages:

1. Installing 40 test pits to establish the extent of the landfill (Figure 1-3, DEH, 1985b).

2. Designing final grades to control runoff and erosion.

3. Installing nine groundwater monitoring wells outside the perimeter of the landfill and constructing a storm drainage system to control surface water runoff at the southwest corner of the landfill.

4. Installing a 30-mil polyvinyl chloride (PVC) membrane cap with gas vents located 400 feet apart and connected under the cap with perforated pipes.

The capping was completed in four phases (see Figure 1-2). In Phase I, 50 acres were capped in October 1986; in Phase II, 15 acres were capped in November 1987; and in Phase III, 9.2 acres were capped in March 1989. Phase IV closure of the last 10 acres was accomplished in two steps: Phase IVA was closed in 1991, and Phase IVB was closed in July 1992 although the membrane cap over Phase IVB was not installed until May 1993.

AOC 18, the asbestos cell, is located in the section of the landfill closed during Phase IV. Between March 1982 and November 1985, an estimated 6.6 tons of asbestos construction debris were placed in the section closed during Phase IVA. A new asbestos cell was opened in 1990 in the section closed during Phase IVB and was used for disposal of small volumes of asbestos-containing material until July 1992.

Plow Shop Pond is a shallow, 30-acre pond outside the installation boundary, northeast of the landfill. It is the furthest downstream of a chain of six ponds (Long Pond, Sandy Pond, Flannagan Pond, Balch Pond, Grove Pond, and Plow Shop Pond) in the Town of Ayer, and is downstream of Bare Hill Pond and Bower's Brook in the Town of Harvard. It receives drainage from approximately 17 square miles in the towns of Groton, Ayer, and Harvard.

The eastern shore of Plow Shop Pond is formed by a railroad causeway constructed in the 1800s. A stone arch culvert under the causeway connects the pond with Grove Pond. Water elevation in Plow Shop Pond is controlled at approximately 216 feet above sea level (ASL) by a dam located at the northwest corner of the pond. The central portion of the pond is approximately eight feet deep. A maximum depth of about 10 feet occurs in the northeast arm of the pond. The discharge from the dam forms Nonacoicus Brook, which flows about 1 mile northwest before its confluence with the Nashua River.

At one time, Plow Shop Pond discharged through a canal, now blocked, at a sawmill at the northeast corner of the pond near the present location of the G.V. Moore Lumber Co. During periods of relatively low stream flow, the Plow Shop Pond dam also controls the water elevation in Grove Pond. However, during periods of high stream flow, the culvert under the railroad causeway restricts flow to Plow Shop Pond, and the elevation of Grove Pond may be 2 feet or more above that of Plow Shop Pond.

The area south of Plow Shop Pond and east of Shepley's Hill Landfill was the site of a railroad roundhouse operated by the Boston and Maine Railroad between 1900 and 1935. Figure 1-4 shows the approximate extent of the former railroad facilities as indicated on a 1934 railroad drawing (B&M RR, 1934). The property formerly occupied by the roundhouse facilities is now owned by the Army. Guilford Transportation Industries operates an extensive, active railyard adjacent to the former roundhouse facilities.

From 1854 through 1961, the area east of the railroad causeway at the northwest corner of Grove Pond was the site of a tannery (Wilson, 1961a, 1961b). The tannery changed ownership several times and operated intermittently between 1900 and 1944. From December 1944 until destroyed by fire in June 1961, this was a successful cattlehide tannery with facilities including a beam-house for hide unhairing and a tan-house for chrome-tanning.

The tannery is of interest because of its waste disposal practices and its potential as a source of contaminants, especially arsenic, chromium, lead, and mercury, to Grove and Plow Shop ponds. Before 1953, process wastewater from the tannery was discharged to Grove Pond with little or no treatment (Fay, 1993; Taylor, 1953; Power, 1957). In addition, a dump was located on tannery property between the tannery and Grove Pond (Fay, 1993; Fillebrown, 1993; Naparstek, 1993). The dump's specific location is suggested by the gradual filling-in of an embayment in Grove Pond as discernable in aerial photographs taken in 1943, 1952, and 1965 (Detrick, 1991, Figures 14, 15, and 16). As early as 1944, the Town of Ayer and the Commonwealth of Massachusetts were concerned about contamination of Grove Pond by the tannery, and in 1949 the town began the process of borrowing funds to connect the tannery to the local wastewater treatment plant (Town of Ayer, 1950; Wilson, 1961a and b). The connection was completed on April 17, 1953 (Taylor, 1953).

1.2.2 Cold Spring Brook Landfill

Cold Spring Brook Landfill (AOC 40) occupies approximately 4 acres along the edge of Patton Road in the southeastern part of the Main Post. It extends for approximately 800 feet along Patton Road and out into the former wetland along Cold Spring Brook, now mostly submerged beneath Cold Spring Brook Pond (Figure 1-5). The 3.5-acre pond was created by the raised inlet of the Patton Road culvert between 1965 and 1972, as shown in aerial photographs from that period. The pond has a surface elevation of approximately 240 feet ASL, and a depth that ranges from less than 1 foot at its western end to a maximum of about 6 feet near its eastern end. The aerial photographs also show that Patton Road used to curve around the Cold Spring Brook wetland before realignment during the mid-to-late 1960s (Detrick, 1991, Figures 21, 22, 23). Remnants of the old roadbed are still visible between well CSB-3 and Patton Road.

South of the old roadbed is a flat area with little vegetation that appears to have been excavated for gravel and sand. Beyond the apparent excavation area, a low hill covered with trees rises abruptly to about 350 feet ASL. Previous studies have not identified any landfilling in this area.

Cold Spring Brook Landfill is considered abandoned, and was identified in November 1987 when 14 55-gallon drums were discovered along the edge of Cold Spring Brook Pond. An identification number on the drums indicated that the

original contents of several had been antifreeze manufactured by Union Carbide and that the drums were 15-to-20 years old. Apparently, the drums had been painted yellow and reused (USAEHA, 1988). A response team from a Union Carbide facility in New Hampshire examined the drums in March 1988, identified seven Union Carbide drums, and sampled their contents. Analysis revealed the presence of chlorinated solvents, and metals (USAEHA, 1988). Other wastes at the landfill include concrete slabs, wire, storage tanks, rebar, timber, and debris (USAEHA, 1988).

The upper surface of the landfill is gently sloping and is about 250 to 260 feet ASL. It is densely covered with small trees and scrub, the trees being predominantly pines. The edge of the landfill falls off abruptly to the wetland or to the pond with an elevation drop that typically ranges between 10 and 20 feet.

Patton Well, one of four water supply wells for Fort Devens, is located south of Patton Road, about 600 feet west of the landfill. The well is screened from 46 to 76 feet below ground surface (bgs), and appears to tap the same aquifer as that monitored by the landfill wells. The well operates on an on-demand basis at approximately 800 gallons per minute (gpm). Total daily withdrawal depends on demand, but is typically 400,000 to 450,000 million gallons per day. The Fort Devens Ammunition Supply Point (ASP or Magazine Area) lies west of the pond, and Cold Spring Brook originates as drainage from a wetland in the center of this area. The brook drains north to Grove Pond, passing through several palustrine forested or scrub/shrub wetlands before reaching it.

The U.S. Army Environmental Hygiene Agency (USAEHA) completed a hydrological investigation of AOC 40 in 1988 (USAEHA, 1988). Locations of the eight wells installed by USAEHA are shown in Figure 1-5. The investigation showed that the landfill is located over glacial sand and gravel deposits in, or adjacent to, a former wetland. U.S. Geological Survey (USGS) information indicates the area is underlain by swampy deposits of muck and peat with adjacent units of sand and gravel from kame deposits.

2.0 DATA GAP ACTIVITIES

2.1 FIELD INVESTIGATIONS PROGRAM AT SHEPLEY'S HILL LANDFILL

The investigations at Shepley's Hill Landfill were conducted in conformance with the following documents:

- Data Gap Activities Work Plan (ABB-ES, 1993a)
- Project Operations Plan Vols. I,II,III (ABB-ES, 1992b)

The following subsections describe the field program activities.

2.1.1 Plow Shop Pond Sediment Sampling

ABB-ES subcontracted Rossfelder Corporation of San Diego, California, to collect 25 sediment cores within Plow Shop Pond (Figure 2-1). A 5-foot length of 4-inch-diameter, thin wall aluminum pipe fitted with a polypropylene liner was used to collect all of the sediment cores except SHD-92-01X, SHD-92-08X, SHD-92-09X, and SHD-92-21X where a 9.5-foot length of 4-inch diameter pipe was used. The standard sampling procedure consisted of vibrating the sampling tube into the sediment with a high frequency vibratory drive head from a floating platform and then winching the tube out. Upon removal of the sampling tube from the sediment, the ends were covered with polypropylene to preserve sample integrity.

The sediment cores were then taken to a staging area on shore where the samples were logged by an ABB-ES geologist. To examine the sediment core directly, the drive shoe was removed and the polypropylene liner and core were extruded into a decontaminated trough, revealing the sediment core for visual logging and sampling. As the core liner was opened, a photoionization detector (PID) was used to monitor total volatile organic compounds (VOCs) in the breathing zone and in the core.

ABB-ES personnel logged descriptions of the core and other relevant conditions, collected reference samples and samples for chemical analyses. Analytical samples were placed in pre-labeled sample jars and stored in coolers with ice to

maintain a temperature below 4-degrees Celsius. Reference samples were analyzed for grain-size distribution. Each sediment sample was analyzed for Project Analyte List (PAL) pesticides and polychlorinated biphenyls (PCBs), total inorganics, total organic carbon (TOC), and percent solids. In addition, Toxicity Characteristic Leaching Procedure (TCLP) extracts were prepared for samples SHD-92-03X at 0 and 3 feet; SHD-92-08X at 0, 4 and 7 feet; and SHD-92-14X at 0 and 3 feet and analyzed for eight Resource Conservation and Recovery Act (RCRA) metals. If sediment recovery was 3 feet or greater, the core was sampled at the 0 to 1 foot interval, at the base of the sediment layer, and at the midpoint between the surface and bottom of the sediment layer. The viscous nature of the surficial sediments and sample volume requirements necessitated sampling from the 0 to 1 foot interval, instead of the 0 to 6 inch interval specified in the Data Gap Activities Work Plan (ABB-ES, 1993a). As a result of poor recovery, SHD-92-11X yielded only a single surface sediment sample. Because of the thin sediment layers, a surface sediment sample and a soil sample were collected from SHD-92-03X and SHD-92-19X at 2.2 feet and 1.5 feet, respectively. Sampling locations SHD-92-04X, SHD-92-07X, and SHD-92-22X were sampled only at the surface and at the base of exploration because of recovery of less than 3 feet. SHD-92-18X was sampled at the surface and bottom of sediment along with a soil sample collected from the base of the exploration. SHD-92-01X was sampled at the surface, midpoint, and bottom of sediment a soil sample was taken from the bottom of the exploration. Table 2-1 summarizes sample depths, media, and the results of grain-size distribution analyses. Complete results of grain-size distribution analyses are provided in Appendix D. Sediment core logs are provided in Appendix A.

A shallow sediment sample was also collected at each of three macroinvertebrate sampling stations to document sediment characteristics (see Figure 2-1). SHD-92-26X, SHD-92-27X, and SHD-92-28X were analyzed for PAL pesticides and PCBs, PAL inorganics, TOC, and grain-size distribution. Table 2-1 summarizes sample depths and grain size distribution.

2.1.2 Nonacoicus Brook Wetland Shallow Groundwater and Soil Sampling

Shallow groundwater and soil samples were collected from four predesignated sampling locations within Nonacoicus Brook Wetland to aid in the assessment of whether the area is a discharge area for contaminated groundwater from Shepley's Hill Landfill (Figure 2-2). Each location was given two site IDs, SHW-92-01X/

SHD-92-29X, SHW-92-02X/SHD-92-30X, SHW-92-03X/SHD-92-31X, and SHW-92-04X/SHD-92-32X. The first site ID was for shallow groundwater, the second for soil. The Data Gap Activities Work Plan (ABB-ES, 1993a) initially referred to these samples as surface water and sediment; however, upon examination of the locations during sampling, it was determined that the samples were actually shallow groundwater and soil. Lack of standing water at the sampling locations necessitated the digging of four 2.5-foot-to-3-foot deep sumps. The sumps were dug using a shovel that was decontaminated prior to the first sump and before digging each subsequent sump. The sumps were covered with plywood and groundwater was allowed to seep in and equilibrate for at least 24 hours. Shallow groundwater samples were collected in the following manner: total VOCs were monitored by PID above the water surface, and temperature, pH, and specific conductance were monitored in situ. Before sample collection, all water sample jars (except VOC vials) were triple rinsed with sample water. The appropriate pre-labeled sample jars were then filled by direct immersion immediately below the water surface except for the dissolved inorganic sample, which was collected using a peristaltic pump and 0.45-micron in-line filter. Water samples were preserved in the field in accordance with the requirements of the Project Operations Plan (POP) (ABB-ES, 1992b). All shallow groundwater samples were analyzed for PAL VOCs, pesticides and PCBs, explosives, total inorganics, dissolved inorganics, TOC, total suspended solids (TSS), total dissolved solids (TDS), and alkalinity.

Upon completion of groundwater sampling, two soil samples were collected from each location, a surface sample and a deeper sample from 1 to 2 feet. Samples were collected by scraping an undisturbed side of the sump with a stainless steel spatula and placing them in pre-labeled sample jars. All sampling equipment was decontaminated prior to use at each sample location and between individual samples. Samples were stored on ice in coolers prior to shipment to the laboratory. Reference soil samples were sent to the laboratory to be tested for grain-size distribution. All soil samples were analyzed for PAL VOCs, pesticides and PCB, explosives, total inorganics, and TOC. TCLP extracts of shallow soil samples collected at SHD-92-29X, CSD-92-12X, and SHD-92-30X were also analyzed for eight RCRA metals. Sample depths and results of grain size distribution analyses are provided in Table 2-2.

2.1.3 Shepley's Hill Landfill Leachate Sampling

A visual survey was conducted along the perimeter of Shepley's Hill Landfill following a 24-hour rain event. Surface water was observed to be flowing in drainage ditches along the perimeter of the landfill and across the landfill cap from SHL-1 toward SHL-3. The reconnaissance failed to locate any signs of groundwater or leachate seeps.

2.1.4 Seismic Refraction Survey

A seismic refraction survey was conducted around the Shepley's Hill Landfill to characterize the topography of subsurface refractors, specifically bedrock and the saturated zone (Figure 2-3). Plans to traverse the landfill were abandoned to prevent damage to the landfill cap and because the landfill material would render seismic velocity data unusable. Four seismic profiles were made. Seismic Line 1 extended 1,900 feet along the southern portion of the landfill bending to the northeast at the southeastern extent of the capped portion. Refraction Line 2 ran 2,770 feet along the eastern side of the landfill cap from the southeastern corner of the landfill to the northern end. Line 3 extended 800 feet along the northern portion of the landfill in an east-northeasterly direction. Seismic Line 4 was 400 feet long and ran due east from Station 8+00 of Seismic Line 2 towards SHM-93-18B (see Figure 2-3).

Seismic lines were performed using two 200-foot, 12-channel seismic spread cables for a 400-foot seismic spread. Seismic spreads were placed end to end to produce continuous subsurface seismic profiles. The spacing between geophones along the spread cables was 20 feet, although the last three geophones on each seismic spread cable were 10 feet apart to facilitate resolution of near-surface seismic velocity variations.

Energy generation points were placed at 100-foot intervals along each seismic spread: one at each end (000 feet and 400 feet), one at the midpoint (200 feet), and one at each of the quarterpoints (100 feet and 300 feet), for a total of five detonation points. An individual charge was made up of one-half pound of 40 percent dynamite primed with a zero-delay electronically detonated blasting cap. The charges were placed in 3.5-to-4-foot deep bar-driven holes.

Seismic data were analyzed primarily by SIPT2, a seismic refraction inverse modeling program originally developed by the USGS, but now marketed commercially by Rimrock Geophysics, Inc., of Lakewood, Colorado. Seismic refraction profiles are shown in Figure 2-4.

2.1.5 Landfill Gas Migration Survey

Landfill gas monitoring was conducted at 21 locations within Shepley's Hill Landfill to assess whether landfill gasses were migrating from below the existing landfill cap (Figure 2-5). All samples were analyzed for methane and selected PAL VOCs using a field gas chromatograph (GC) with concentration trap and an electron capture detector/flame ionization detector (ECD/FID):

- methane
- benzene
- chloroethene (vinyl chloride)
- chloroform
- 1,1-dichloroethane
- 1,2-dichloroethane
- 1,1-dichloroethene *
- C-1,2-dichloroethene *
- T-1,2-dichloroethene *
- ethylbenzene *
- methylene chloride
- 1,1,2,2-tetrachloroethane
- tetrachloroethene
- toluene *
- 1,1,1-trichloroethane *
- trichloroethene
- meta/para-xylene *
- ortho-xylene *

In addition to the target compounds listed in the Data Gap Activities Work Plan, field personnel were able to analyze for eight related sister/daughter compounds (indicated with an *) that can be indicators of the target compounds. Interferences experienced under field conditions prevented successful analysis of two compounds (chlorobenzene and chloroethane) listed in the work plan.

Samples were collected from 16 TerraProbe borings located around the perimeter of the landfill. All the samples were collected from a depth of 10 feet except SG-1,SG-5,SG-6,SG-10, and SG-11, which were collected at 3 feet, and SG-16 sampled at 6 feet. These samples were collected at the lesser depths because of the shallow water table at the sampling locations. Adverse field conditions prevented collection of samples from several planned locations along the southern and western landfill edge. These samples were relocated during the field program.

Analyses were also performed on gasses collected from five existing landfill vents installed through the landfill cover.

2.1.6 Monitoring Well Installation

ABB-ES installed five monitoring wells at Shepley's Hill Landfill to obtain further data on groundwater flow, aquifer characteristics, potential contamination transport routes, and to obtain reference soil and rock samples from both the bedrock and overburden aquifers (Figure 2-6). SHM-93-18B was installed as a deep overburden well adjacent to SHL-18. SHM-93-10C and SHM-93-22C were installed as bedrock wells adjacent to SHL-10 and SHL-22, respectively. SHM-93-24A and SHM-93-01A were installed as water table wells.

The water table wells were installed with 6.25-inch inside diameter (ID) hollow-stem augers (HSAs). The deep overburden well, SHM-93-18B, was installed by first advancing 3-inch ID casing by the drive and wash method to facilitate collection of split-spoon samples. The 3-inch ID casing was advanced to bedrock and then withdrawn from the hole. Drilling water was not recirculated when advancing the 3-inch casing to lessen the chance of cross-contamination within the overburden aquifer. Refer to Subsection 2.7, Investigation Derived Waste (IDW), for a description of drilling fluid screening. Split-spoons were collected from the overburden borings at 5-foot intervals. Reference samples were collected from the split-spoons and visually logged. Analytical soil samples were collected from split-spoons obtained from within the screened interval of the overburden monitoring wells. These soil samples were analyzed for TOC only. Once the 3-inch ID casing had been removed, 6.25-inch ID HSAs were then advanced to bedrock to allow well installation.

The bedrock wells were installed by advancing 6-inch casing to bedrock using the drive and wash method and seating the casing into bedrock to prevent drilling water used in the bedrock from escaping to the overburden aquifer. Borings were advanced into bedrock using an H-series core barrel 5 feet in length. Rock cores were collected, visually logged, and stored on site. Upon completion of coring, the hole was over-reamed with a 5.625-inch outside diameter (OD) roller cone to allow for proper well installation. Although drilling water was recirculated in the overburden with the approval of USAEC, overburden drilling water was pumped from the casing prior to coring. No split-spoons were collected from the overburden during installation of the bedrock wells. Table 2-3 presents depths and soil classifications for samples collected from the Shepley's Hill Landfill borings. Boring logs and core logs are provided in Appendix A.

The water, filter sand, and bentonite used for well installation were approved by the USAEC prior to the start of the drilling program. The well screen consisted of 10-foot-long, 4-inch ID, 0.010-inch machine slotted, Schedule 40 PVC pipe with a flush-threaded bottom plug. Riser material was 4-inch ID, flush-threaded, Schedule 40 PVC and extended approximately 2.5 feet above ground surface. A loose fitting cap was placed on top of the riser section to protect against the entry of water while allowing for equalization of the well water with atmospheric pressure. Filter sand was placed in the annulus between the well casing and the wall of the borehole to a level of 5 to 6 feet above the top of the well screen. Care was taken to prevent voids in the filter and to prevent contact between the well screen and the formation. Above the filter sand, a 5 to 6-foot bentonite pellet or tremie-placed bentonite slurry seal was installed. When bentonite pellets were used as seal material, the pellets were hydrated before proceeding with well installation. Upon completion of the bentonite seal placement, grout in the ratio of 20 parts Portland Type II cement to 1 part bentonite powder was tremie-emplaced in the well annulus from the top of the bentonite seal to ground surface. The well was completed by placement of a 5-foot-long, 6-inch ID protective steel casing 2.5 feet into the grout and 2.5 feet above ground surface. The protective casing was fitted with a locking cap. Four protective steel posts were installed around the well, and a 6-inch-thick gravel pad was placed about the well to aid in drainage.

Water table wells were installed with 8 to 6 feet of the screen below the water table and 2 to 4 feet above the water table to allow for seasonal fluctuations. Bentonite pellets were used as seal material on water table wells. The screens of

the bedrock wells were placed and sealed entirely in bedrock. To prevent the borehole from acting as a conduit for groundwater between the overburden and bedrock aquifers, a 6-foot bentonite seal was installed straddling the bedrock-overburden interface. Bentonite chips were used in SHM-93-10C and bentonite slurry was used in SHM-93-22C. Table 2-4 summarizes well construction details. Monitoring well construction forms are provided in Appendix B.

2.1.7 Aquifer Characterization and Testing

In situ measurements were made to assess groundwater flow paths and aquifer characteristics.

Groundwater flow patterns were established from four installation-wide water-level measurement rounds. Water levels were recorded in monitoring wells and surface water bodies. Measurements in wells were made from surveyors' marks using electronic water-level sensors. Surface water measurements were made by measuring from survey marks on stakes placed in or near the water. Water levels were measured to the nearest 0.01 foot and were referenced to the National Geodetic Vertical Datum (NGVD) of 1929. Appendix E presents basewide water level data.

To obtain an estimate of permeability variations within the unconsolidated and bedrock aquifers, a series of rising-head slug tests were performed on the five new wells installed within the Shepley's Hill Landfill area. Water displacement for the tests was accomplished by lowering a 3-foot-long, 3-inch-diameter, solid PVC cylinder 4 to 5 feet below the water table. The water level in the well was allowed to equilibrate and the slug was withdrawn causing the water level to fall. The head recovery was recorded using an In-Situ™ Hermit SE1000C Data Logger and a 10 pound-per-square-inch (PSI) pressure transducer. Rising-head tests were performed to reduce inertial effects and initial oscillation of the water table, yet still achieve maximum stress to the aquifer.

Two tests were performed on each well, except SHM-93-22C, to assess variations associated with testing. Only one test was performed on SHM-93-22C because of an exceptionally slow recovery of 8 to 10 hours. Test data were analyzed using the methods of Hvorslev (1951) and Bouwer and Rice (1976). Permeability

estimates and water level data are presented in Table 2-5. Test data and calculations are provided in Appendix C.

2.1.8 Monitoring Well Development

A total of 27 monitoring wells (22 existing and five new) at Shepley's Hill Landfill were developed prior to the first round of groundwater sampling (see Figure 2-6). Development was conducted to:

- remove foreign substances potentially introduced during drilling
- increase the efficiency of the wells
- restore the hydrogeologic integrity of the formation immediately adjacent to the well
- reduce the turbidity of groundwater samples

Development of the five newly installed wells, SHM-93-01A, SHM-93-10C, SHM-93-18B, SHM-93-22C, and SHM-93-24A, was initiated no sooner than 48 hours and no later than seven days after monitoring well completion. Submersible stainless steel pumps and dedicated plastic Whale pumps were used for development. The stainless steel pump was decontaminated before use in each well, and the Teflon™ tubing used was replaced between each well. Dedicated plastic Whale pumps and 0.25-inch polyethylene tubing were used to develop all existing wells.

During development, each well volume of removed water was monitored for specific conductance, temperature, pH, and turbidity. A well volume was calculated as the volume of standing water in the well plus the amount in the annular sandpack (assuming 30 percent porosity).

Wells were considered fully developed when the following criteria were met:

- Well water was clear to the unaided eye.
- Sediment thickness in the well was less than 1 percent of the screen length.

- Total water removed from the well equalled five well volumes plus five times the volume of any drilling water lost.
- Where possible, turbidity measurements varied by less than approximately 10 percent.

Any changes in the above-mentioned development criteria were approved by the USAEC. The bedrock wells were very slow to recharge. A total of 311 gallons of groundwater was purged from SHM-93-22C, equivalent to three well volumes. Approximately 1,100 gallons of groundwater were purged from SHM-93-10C, equivalent to five well volumes plus two times the water lost during drilling. Groundwater purged from wells was contained in drums for disposal characterization. Procedures for handling IDW are described in Subsection 2.7.

2.1.9 Shepley's Hill Landfill Groundwater Sampling

Two rounds of groundwater samples were collected from monitoring wells around Shepley's Hill Landfill. During the first round, 22 existing wells and five newly installed wells were sampled (see Figure 2-6). Only the five newly installed wells were sampled during the second round. Monitoring well SHL-1 was not sampled during either round because it was dry. Newly installed wells were sampled no sooner than 14 days after completion of well development. All wells were purged before sampling to confirm that water sampled is representative of formation water. Purging was performed with dedicated submersible Whale pumps or dedicated Teflon bailers. Total VOCs at the wellhead and in the breathing zone were monitored with a PID before and during purging. Each well volume of water removed during purging was monitored for specific conductance, temperature, pH, and turbidity. Redox potential was measured at the end of purging. A well was considered purged when the volume of groundwater removed was equivalent to five well volumes and the monitored parameters varied by less than approximately 10 percent. SHM-93-22C, SHL-23, SHL-24, and SHL-25 recovered very slowly and fewer than five well volumes were removed.

All wells were sampled with dedicated Teflon bailers. Before filling, all sample jars (except VOC vials) were triple rinsed with groundwater from the monitoring well being sampled. Water was poured directly from bailers into pre-labeled sample jars. If VOCs were to be collected, they were collected before all other samples. All samples were analyzed for PAL SVOCs, VOCs, pesticides and

PCBs, explosives, total inorganics, TOC, TSS, TDS, and alkalinity. Fifty percent of the samples were also analyzed for dissolved inorganics. Samples to be analyzed for dissolved inorganics were collected from the bailer using a peristaltic pump and a 0.45-micron in-line filter to remove suspended solids.

2.1.10 Fish Sampling and Analysis

Fish sampling at Plow Shop Pond was conducted between October 20 and 22, 1992. Fish tissue sampling and analysis was conducted to analyze whole fish and fish fillet samples for contaminants from Shepley's Hill Landfill. Fish sampling was conducted according to guidance presented in the Regulatory Draft Fish Tissue Sampling and Analysis Plan (SAP) (ABB-ES, 1992a).

The study involved dividing the pond into four quadrants (Figure 2-7). A variety of active and passive fishing techniques were employed to characterize the fish community with minimal sample gear bias. At Stations 1 through 3, the fishing effort included electrofishing, gill netting, and trap netting. At Station 4, only electrofishing was conducted. Because fish are mobile organisms and landfill impacts are primarily related to non-point source contaminant loading, each fish sampling location represents a region from which fish were sampled, rather than a fixed point. Sampling stations were selected because of their proximity to Shepley's Hill Landfill and based on existing information regarding contaminant distribution in Plow Shop Pond.

Electrofishing at Plow Shop Pond consisted of sweeping the sampling quadrants with a boat-mounted Coffelt VVP-15 electroshocking unit. This electrofishing unit was operated in an Alternating Current (AC) mode with 230 volts and 4 to 7 amperes. Both day and night electrofishing were conducted. Passive sampling of the Plow Shop Pond fish community included using: (1) 25-foot panels of 2.5-inch experimental gill nets with variable bar mesh (0.5, 1.0, 1.5, 2.0, and 2.5 inch), and (2) trap nets consisting of a steel frame covered with a 1.3-centimeter (cm) nylon knotless bar mesh with a 1 x 2 meter opening. Each trap net consisted of two 8 meter wings and one approximately 33 meter lead.

All fish collected from Plow Shop Pond between October 20 and 21, 1992, were identified to species, weighed to the nearest gram, and measured to the nearest millimeter. Animals captured between October 21 and 22, 1992, received variable processing, ranging from not collecting to identification and full "work-up."

Individual fish were checked for external pathological gross abnormalities (e.g., tumors, lesions, structural or bone defects) through an evaluation of the conditions of the lips, jaws, barbels (when applicable), eyes, right gill, fins, urogenital cavity, anus, body form, and body surfaces. All data were recorded on field data sheets. The results of the pathological evaluation of Plow Shop Pond fish are presented in Section 7.0.

Fish species that commonly occur in warmwater ponds in Massachusetts were chosen as the Plow Shop Pond target species for tissue analysis. Target species were chosen based upon the following criteria: human fishery utilization, abundance, size, ecological importance, position in food chain, and metabolism (USEPA, 1989f). To achieve SAP objectives (ABB-ES, 1992a), the ability to collect sufficient, duplicate, replicate, and/or laboratory quality control (QC) samples was also considered when selecting target species.

The following species were selected as target species:

- Brown Bullhead (*Ictalurus nebulosus*); Yellow Bullhead (*I. natalis*)

  Bullheads are omnivorous bottom feeders of recreational importance. Bullheads are caught for human consumption, and are abundant in warm, shallow ponds of southern New England. During colder months, bullheads are known to bury themselves in muddy pond bottoms, where they remain until warmer months (Werner, 1980). Because of their considerable exposure to pond sediments, bullheads are an ideal organism for tissue contaminant burden analysis.

- Bluegill (*Lepomis macrochirus*)

  Bluegill were sampled to represent a secondary consumer of recreational importance. They are primarily residents of ponds and lakes, but may also occur in quiet waters in streams and rivers. Young bluegill feed on various zooplankton, including cladocerans and copepods, whereas larger fish feed on insects and other invertebrates; on occasion, larger fish are piscivores, eating small fish (Werner, 1980).

- Largemouth bass (*Micropterus salmoides*)

Largemouth bass were chosen to represent a tertiary consumer of recreational importance in Plow Shop Pond. Largemouth bass thrive in weedy lakes, where they feed on invertebrates, frogs, and fishes. To evaluate risks to humans from consumption of fish, specimens of largemouth bass all had lengths greater than their 12-inch minimum legal length limit (Massachusetts Division of Fisheries and Wildlife [MADFW], 1992).

To avoid field contamination, target species were processed minimally in the field and prepared for shipment to the analytical laboratory. Individual fish were weighed to the nearest gram, measured to the nearest millimeter, and a complete external examination of the fish was recorded on field fish health forms. Each individual fish was assigned a unique numerical identification code that identified the fish by water body and served to identify the animal from all others captured for analysis. No fish were filleted in the field.

Fish were placed in sealed bags and labeled according to the SAP (ABB-ES, 1992a). All fish were delivered on ice to the analytical laboratory within 24 to 36 hours, via overnight courier. Once in the analytical laboratory, all samples were logged into the laboratory sample management program.

Largemouth bass and bullhead were skinned and filleted in the laboratory using a Teflon-coated stainless steel microtome blade. Fillets from Plow Shop Pond bass and bullhead were obtained from the left side of individual fish. The right fillet remained on the fish carcass and was processed as "whole fish." The skinless fillets and the remainder of the fish carcass were labeled and frozen until analysis. Because no analysis of sunfish (bluegills) fillets was conducted (whole body analysis only), whole fish were frozen immediately upon arrival at the laboratory. All fish remained frozen until laboratory analysis was conducted.

Because of laboratory error, the initial filleting of the Plow Shop Pond largemouth bass consisted of removal of only a small portion of fillet tissue (enough for laboratory analysis). However, immediately prior to complete homogenizing of the fish carcass for analysis, the remainder of the fillet sample was removed from the fish. Fish were allowed to thaw slightly and the remainder of the fillet was removed using a Teflon-coated stainless steel microtome blade. This second fillet sample was analyzed independently from the first sample removed from the

individual fish. The carcasses (minus the left fillet) were analyzed as "whole fish" for Plow Shop Pond.

To avoid contamination from inorganics associated with stainless steel laboratory instrumentation, whole fish were macerated in a tissue homogenizer with a titanium blade. Whole fish and fillets were analyzed for 22 PAL inorganics, pesticides and PCBs, lipids, and percent solids. Inorganics were analyzed in accordance with USEPA Method 600/4-81/055. Organic analyses were completed as detailed in the SAP (ABB-ES, 1992a). Two matrix spikes and two duplicates were conducted for quality assurance/quality control (QA/QC) purposes.

Results of laboratory analyses are presented in Appendix T and comparisons of the analytical data to state and national data are provided in Appendix N.

2.1.11 Plow Shop Pond Macroinvertebrate Sampling

A semiquantitative inventory of macroinvertebrates was conducted at three sampling stations in Plow Shop Pond (see Figure 2-1). At each sampling station, two duplicate macroinvertebrate samples from vegetation ("phytomacrofauna") and two duplicate samples from sediment ("benthic infauna") were collected. In siting the individual sampling stations, an attempt was made to confirm that the stations were as comparable as possible with respect to water movement, substrate composition, canopy coverage, and water depth. All macroinvertebrate samples were collected in September 1992. In addition, during this same period, additional macroinvertebrate samples were collected from Grove Pond by MADEP.

After selecting the sampling location, a 1-square-meter PVC square was placed over the vegetation. Once the square had settled, phytomacrofauna were collected from submerged macrophytes and the water column with D-frame aquatic dip nets (~600 microns). Phytomacrofauna were collected from within each 1-meter-square sampling station by sweeping the entire region both vertically and horizontally. The contents of the dip net were washed into a number 30 USGS brass sieve. Any invertebrates attached to plant matter or other debris within the sample were carefully removed prior to discarding plant debris. The phytomacrofaunal organisms and the remainder of the sample were placed in labeled jars containing approximately 70 percent ethanol.

An Ekman dredge was used to sample benthic organisms in areas of the pond with silt, muck, or sludge substrates. Depending upon the pond depth at the sampling stations, the dredge was either lowered into the bottom substrate from a boat or was pushed directly into the substrates. After sieving the contents of Ekman dredge samples through a number 30 USGS brass sieve, smaller debris and macroinvertebrates were placed in labeled jars containing approximately 70 percent ethanol.

After samples were transported to the laboratory, they were re-preserved in 70 percent ethanol to avoid preservative dilution from organic matter. A sub-sample was collected from each sample, by evenly distributing the sample in a gridded, light-colored sampling pan. All organisms in randomly chosen grids were picked until 100 organisms were collected. If fewer than 100 organisms were available, the entire sample was selected. Several Chironomid midges were mounted for taxonomic identification. The remainder of the taxa were identified to the lowest feasible taxonomic level (generally the genus level) using compound (1,000-power maximum) and dissecting (80-power maximum) microscopes. All macroinvertebrates collected for taxonomic analysis were placed in sample jars and preserved in 70 percent alcohol.

Information regarding the physical attributes of the aquatic habitat (including nature of the substrate and vegetative characteristics) and water quality parameters (i.e., dissolved oxygen, temperature, pH, and conductivity) was also collected at each sampling station.

Appendix P contains the results of the macroinvertebrate analyses.

2.1.12 Wetland Functional Assessment

A Wetland Evaluation Technique (WET) evaluation was conducted on Plow Shop Pond to assess the functions and values of this wetland. WET is a standardized evaluation technique that provides a rapid assessment of many of the recognized values and functions of a wetland (Adamus et al., 1991). WET uses a standardized manual and answer sheet to provide input data for the WET 2.0 computer program. After data are entered into the WET program, a "Low," "Medium," or "High" value is assigned to each function.

A combination of the following 11 functions (i.e., physical, chemical, and biological characteristics) and values (characteristics beneficial to society) were evaluated through WET at Plow Shop Pond:

- Groundwater Recharge
- Groundwater Discharge
- Floodflow Alteration
- Sediment Stabilization
- Sediment/Toxicant Retention
- Nutrient Removal/Transformation
- Production Export
- Wildlife Diversity/Abundance
- Aquatic Diversity/Abundance
- Uniqueness/Heritage
- Recreation

The above-listed functions and values were evaluated by WET in the following contexts: "Social Significance" (the value of the wetland to society); "Effectiveness" (the capability of the wetland to provide the function); and "Opportunity" (the opportunity of the wetland to provide the function).

The WET analysis determined that the value to society of Plow Shop Pond is "high" for Groundwater Recharge, Groundwater Discharge, Wildlife Diversity and Abundance, and Uniqueness and Heritage. The remainder of the evaluated WET parameters were rated as "low" to "moderate" in social significance. In terms of effectiveness, WET scored Plow Shop Pond as "high" for Sediment/Toxicant Retention and Wildlife Breeding and Migration, and as "low" to "moderate" for the other functions and values in WET. Of the three functions/values evaluated for Opportunity, the opportunity for Plow Shop Pond to perform the Sediment/ Toxicant Retention and Nutrient Removal/Transformation functions is rated as "high" by WET. Plow Shop Pond has the opportunity to provide these functions because the proximity of the adjacent landfill. Floodflow Alteration is rated as "moderate" by WET based upon the high percentage of the watershed this wetland occupies.

The WET functional assessment is included as Appendix O. In addition, this appendix includes a detailed narrative discussion interpreting the results of the WET analysis.

2.2 FIELD INVESTIGATIONS AT COLD SPRING BROOK LANDFILL

The investigations at Cold Spring Brook were conducted in general conformance with the following documents:

- Data Gap Activities Work Plan (ABB-ES, 1993a)
- Project Operations Plan Vol. I, II, III (ABB-ES, 1992b)

The following subsections describe the field program activities.

2.2.1 Cold Spring Brook Pond Sediment Sampling

ABB-ES subcontracted Rossfelder Corporation of San Diego, California, to collect 10 sediment cores within Cold Spring Brook Pond (Figure 2-8). A 5-foot length of 4-inch-diameter, thin wall aluminum pipe fitted with a polypropylene liner was used to collect all the samples except CSD-92-07X and CSD-92-08X where shallow water prohibited access. The standard sampling procedure was to vibrate the sampling tube into the sediment with a high frequency vibratory drive head from a floating platform and then winch the sampling tube out. Upon removal of the sampling tube from the sediment, the ends were covered with polypropylene to preserve sample integrity. The sediment cores were then taken to a staging area on shore where the samples were logged by an ABB-ES geologist. To examine the sediment core directly, the drive shoe was removed and the polypropylene liner and core were extruded into a decontaminated trough, revealing the sediment core for visual logging and sampling. As the core liner was opened, a PID was used to monitor total VOCs in the breathing zone and in the core. ABB-ES personnel logged descriptions of the core and other relevant conditions, collected reference samples, and samples for chemical analyses. Analytical samples were placed in pre-labeled sample jars and stored in coolers with ice to maintain a temperature below 4-degrees Celsius. Reference samples were analyzed for grain-size distribution. All analytical samples were tested for PAL semivolatile organic compounds (SVOCs), pesticides and PCBs, total inorganics, explosives, TOC, and percent solids.

In addition, three samples were analyzed for TCLP, CSD-92-01X at 2 feet, CSD-92-09X at 3 feet, and CSD-92-09X at 5 feet. If core recovery was 3 feet or

greater, the core was sampled from the 0 to 1 feet interval, at the base of the core, and at the midpoint between the top and bottom of the core. The viscous nature of the surficial sediments and sample volume requirements necessitated sampling from the 0 to 1 foot interval, instead of the 0 to 6 inch interval specified in the Data Gap Activities Work Plan (ABB-ES, 1993a). Because of refusal, CSD-92-10X yielded only two sediment samples. CSD-92-07X and CSD-92-08X were driven using a sledgehammer and retrieved by hand. Because of the poor recovery associated with this technique, only two samples were collected from each core. Table 2-6 summarizes sample depths and the results of grain-size distribution samples. Complete results of grain-size distribution analyses are provided in Appendix D. Sediment core logs are provided in Appendix A.

A shallow sediment sample was also collected at each of three macroinvertebrate sampling stations to document sediment characteristics (Figure 2-8). CSD-92-14X, CSD-92-15X, and CSD-92-16X were analyzed for PAL SVOCs, pesticides and PCBs, total inorganics, TOC, and grain-size distribution. Table 2-6 summarizes sample depths and grain-size distribution. Complete results of grain-size distribution analyses are provided in Appendix D.

2.2.2 Cold Spring Brook Landfill Seep Sampling

Surface water and sediment samples were collected from three predesignated sampling locations along the northern and western edges of the Cold Spring Brook Landfill (see Figure 2-8). Samples were collected from suspected seep locations to evaluate whether Cold Spring Brook is a discharge area for contaminated groundwater emanating from the Cold Spring Brook Landfill. Each sample location was given two site IDs, CSW-92-01X/CSD-92-11X, CSW-92-02X/CSD-92-12X, and CSW-92-03X/CSD-92-13X. The first site ID was for the surface water sample and the second for the sediment samples. Surface water samples CSW-92-01X, CSW-92-02X, and CSW-92-03X were collected in the following manner: total VOCs were monitored by PID above the surface water, and temperature, pH, and specific conductance were monitored in situ. Prior to sample collection, all water sample jars (except VOC vials) were triple rinsed with sample water. The appropriate pre-labeled sample jars were then filled by direct immersion immediately below the surface of the water except for dissolved inorganic samples, which were collected using a peristaltic pump and 0.45-micron in-line filter. Water samples were preserved in the field in accordance with the requirements of the POP (ABB-ES, 1992b) and stored on ice in coolers prior to

shipment to the laboratory. All surface water samples were analyzed for PAL SVOCs, pesticides and PCBs, explosives, total inorganics, dissolved inorganics, TOC, TSS, TDS, and alkalinity.

Upon completion of surface water sampling, two sediment samples were collected from each location, one from the surface and the other from a depth of 1 foot. Samples were collected using a hand auger and stainless steel spatula and placed in pre-labeled sample jars. All sampling equipment was decontaminated prior to use at each sample location and between individual samples. Sediment samples were stored on ice in coolers prior to shipment to the laboratory. Reference samples were sent to the laboratory to be tested for grain-size distribution and moisture content. All sediment samples were tested for PAL SVOCs, pesticides and PCBs, explosives, total inorganics, and TOC. TCLP extracts of surficial sediment samples collected at CSD-92-11X and CSD-92-12X were also analyzed for eight RCRA metals. Table 2-6 summarizes sample depths and results of grain size distribution analyses. Complete results of grain size distribution analyses are provided in Appendix D.

2.2.3 Magazine Area Shallow Groundwater and Soil Sampling

Shallow groundwater and soil samples were collected from three locations along drainage ditches in the southwest corner of the Magazine Area to assess its potential contribution to contamination in Cold Spring Brook (see Figure 2-8). Each sample location was given two site IDs, MAW-92-01X/MAD-92-01X, MAW-92-02X/MAD-92-02X, and MAW-92-03X/MAD-92-03X. The first site ID designates the shallow groundwater sample and the second designates the soil sample. The Data Gap Activities Work Plan (ABB-ES, 1993a) initially referred to these samples as surface water and sediment; however, upon examination of the sample locations during sampling, it was determined that the samples were actually shallow groundwater and soil. Lack of standing water at the sampling locations necessitated the digging of three 2-to-5-foot-deep sumps. The sumps were dug with a shovel that was decontaminated prior to the first sump and before digging each subsequent sump. The sumps were covered with plywood and the groundwater was allowed to seep in and equilibrate for at least 24 hours. The sump at site MAW-92-02X was dug to a depth of 5 feet and failed to produce water within 24 hours; therefore, the site was not sampled for groundwater. Shallow groundwater samples MAW-92-01X and MAW-92-03X were collected in the following manner: total VOCs were monitored by PID above the surface

water, and temperature, pH, and specific conductance were measured in situ. Prior to sample collection, all water sample jars (except VOC vials) were triple rinsed with sample water. The appropriate pre-labeled sample jars were then filled. VOCs were collected first by direct immersion immediately below the surface of the water. All other samples were then collected using a peristaltic pump at a rate of 0.5 gpm. The dissolved inorganics sample was collected using the peristaltic pump and a 0.45-micron in-line filter. Water samples were preserved in the field in accordance with the requirements of the POP (ABB-ES, 1992b) and stored on ice in coolers. All groundwater samples were analyzed for PAL SVOCs, pesticides and PCBs, explosives, total inorganics, dissolved inorganics, TOC, TSS, TDS, and alkalinity.

Upon completion of surface water sampling, a soil sample was collected from the side of the excavation at a depth of 0.5 foot. Samples were collected using a stainless steel spatula, placed in pre-labeled sample jars, and stored on ice in coolers prior to and during shipment to the laboratory. All sampling equipment was decontaminated prior to use at each sample location. Reference samples were sent to the laboratory to be tested for grain-size distribution and moisture content. All soil samples were analyzed for PAL SVOCs, pesticides and PCBs, explosives, total inorganics, and TOC. Table 2-7 summarizes sample depths and grain-size distribution. Complete results of grain-size distribution analyses are provided in Appendix D.

2.2.4 Soil Boring and Monitoring Well Installation

ABB-ES installed three monitoring wells in the vicinity of the Cold Spring Brook Landfill to obtain further information on groundwater flow, aquifer characteristics, potential contaminant migration pathways, and to obtain reference and geologic soil samples from the overburden aquifer.

CSM-93-01A was installed as a deep overburden well through the landfill material approximately 30 feet south of the existing well CSB-4 (see Figure 2-8). CSM-93-02A, a water table well, and CSM-92-02B, a deep overburden well, were installed as a nested pair on the south side of Patton Road between Patton Well and the existing well CSB-2. To lessen the chance of cross-contamination, drilling fluids were not recirculated at any time during drilling activities in the Cold Spring Brook Landfill area. Refer to Subsection 2.7 for a description of drilling fluids screening.

The landfill monitoring well, CSM-93-01A, was installed by first advancing 4.25-inch ID HSAs to find an unobstructed route through the landfill material. The 4.25-inch ID HSAs were advanced to 20 feet bgs and spoons were overdriven to 26 feet bgs to ensure that the HSAs were beyond landfill material. The HSAs were then withdrawn and 6-inch ID casing was advanced by the drive and wash method to 39 feet bgs. Two-inch split-spoons were collected at 2-foot intervals from 28 to 38 feet bgs. All split-spoons were field screened for total VOCs with a PID and reference samples were collected for geologic classification. An analytical sample for TOC analysis was collected from the split-spoon at 28 to 30 feet. At 39 feet bgs, the 6-inch casing became stuck, and 5-inch ID casing was telescoped inside the 6-inch casing and advanced to 65.5 feet bgs. Split-spoons were collected at 5-foot intervals from 42 to 65.5 feet bgs. The 5-inch ID casing was withdrawn during well installation. To prevent the borehole from acting as a conduit for contaminant migration between the landfill and underlying aquifer, the 6-inch ID casing was permanently grouted in place.

CSM-93-02A was installed by first advancing a 4.25-inch ID HSA to a depth of 45 feet bgs. Because of flowing sand conditions, 3-inch ID casing was then advanced by drive and wash to facilitate collection of split-spoons. The 3-inch ID casing was advanced to bedrock at a depth of 129.5 feet bgs to further characterize the overburden aquifer and geologic conditions and then withdrawn. Split-spoons were collected at 5-foot intervals from 10 feet bgs to 129.5 feet bgs. The split-spoons were field screened for VOCs with a PID, reference samples were collected, and the samples were visually logged. Reference samples were sent to the laboratory to be tested for grain-size distribution. Analytical samples were collected from the 25 to 27 foot and 55 to 57 foot intervals to be analyzed for TOC. After removal of the 3-inch ID casing, well CSM-93-02A was installed at 31.5 feet bgs using 6.25-inch ID HSAs. CSM-93-02B was installed using 6.25-inch ID HSAs to a depth of 67 feet bgs. No split-spoons were collected during the CSM-93-02B borehole installation. Table 2-8 summarizes the Cold Spring Brook Landfill soil borings. Complete results of grain-size distribution are provided in Appendix D. Boring logs are provided in Appendix A.

The water, filter sand, and bentonite used for all monitoring well installations were approved by the USAEC prior to the start of the drilling program. The well screens consisted of 10-foot long, 4-inch ID, 0.010-inch machine slotted, Schedule 40 PVC pipe with a flush-threaded bottom plug. Riser material was 4-inch ID, flush-threaded, Schedule 40 PVC and extended approximately 2.5 feet above

ground surface. A loose fitting cap was placed on top of the riser section to protect against the entry of water while allowing for equalization of the well water with atmospheric pressure. Filter sand was placed in the annulus between the well casing and the wall of the borehole to a level of 5 to 10 feet above the top of the well screen. Care was taken to prevent voids in the filter and to prevent contact between the well screen and the formation. Above the filter sand, a 4 to 6 foot bentonite chip or tremie-placed bentonite slurry seal was installed. When bentonite chips were used as seal material, the chips were hydrated prior to proceeding with well installation. Upon completion of bentonite seal placement, grout in the ratio of 20 parts Portland Type II cement to 1 part bentonite powder was tremie-placed in the well annulus from the top of the bentonite seal to ground surface. The monitoring wells were completed by placement of a 5-foot-long, 6-inch ID protective steel casing 2.5 feet into the grout. The protective casing was fitted with a locking cap. Four protective steel posts were installed around the well, and a 6-inch thick gravel pad was placed about the well to aid drainage. Table 2-9 presents details of Cold Spring Brook Landfill monitoring well construction. Monitoring well construction diagrams are provided in Appendix B.

2.2.5 Aquifer Testing

In situ measurements were made to assess groundwater flow paths and aquifer characteristics.

Groundwater flow patterns were determined from five installation-wide water-level measurement rounds. Water levels were recorded in monitoring wells and surface water bodies. Measurements in monitoring wells were made from surveyors' marks using electronic water level sensors. Surface water measurements were taken by measuring from survey marks on stakes placed in or near the water. Water levels were measured to the nearest 0.01 foot and were referenced to the NGVD of 1929. Basewide water level rounds are summarized in Appendix E.

A series of rising-head slug tests were performed on the three new monitoring wells installed in the vicinity of Cold Spring Brook Landfill (see Figure 2-8) to obtain an estimate of permeability variations within the unconsolidated aquifer. Tests were performed by lowering a 3-foot-long, 3-inch-diameter, solid PVC cylinder 4 to 5 feet below the water table. The water level in the well was

allowed to equilibrate and the slug was withdrawn causing the water level to fall. The head recovery was recorded using an In-Situ Hermit SE100C Data Logger and a 10-PSI pressure transducer. Rising-head tests were performed to reduce inertial effects and initial oscillation of the water table, yet still achieve maximum stress to the aquifer. Two tests were performed on each well to assess variations associated with each test. Test data were analyzed using the methods of Hvorslev (1951) and Bouwer and Rice (1976). Table 2-10 summarizes permeability estimates and water level data for monitoring wells in the Cold Spring Brook Landfill area. Test data and calculations are provided in Appendix C.

2.2.6 Monitoring Well Development

All 11 monitoring wells (eight existing and three new) at the Cold Spring Brook Landfill were developed prior to the first round of groundwater sampling (see Figure 2-8). Development was conducted to:

- Remove foreign substances potentially introduced during drilling
- Increase the efficiency of the wells
- Restore the hydrogeologic integrity of the formation immediately adjacent to the well
- Reduce the turbidity of groundwater samples

Development of the three newly installed monitoring wells, CSM-93-01A, CSM-92-02A, and CSM-93-02B, was initiated no sooner than 48 hours and no later than seven days after monitoring well completion. Submersible stainless steel pumps and dedicated plastic Whale pumps were used for development. The stainless steel pump was decontaminated before use in each monitoring well and the Teflon hose was changed between monitoring wells. Dedicated plastic Whale pumps and 0.25-inch polyethylene tubing were used to develop existing monitoring wells CSB-1 through CSB-8.

During development, each well volume of water removed was monitored for specific conductance, temperature, pH, and turbidity. A well volume was calculated as the volume of standing water in the well plus the amount in the annular sandpack (assuming 30 percent porosity).

Wells were considered fully developed when the following criteria were met:

- Well water was clear to the unaided eye.
- Sediment thickness in the well was less than 1 percent of the screen length.
- Total water removed from the well equalled five well volumes plus five times the volume of any drilling water lost.
- Where possible, turbidity measurements varied by less than approximately 10 percent.

CSB-4 and CSB-5 were very slow to recharge and fewer than five well volumes were removed. Groundwater purged from monitoring wells was contained in drums for disposal characterization. Procedures for handling purge water are described in Subsection 2.7.

2.2.7 Cold Spring Brook Landfill Groundwater Sampling

Two rounds of groundwater samples were collected from the monitoring wells around the Cold Spring Brook Landfill. During the first round, a total of 12 monitoring wells, all of the new and existing monitoring wells, as well as Patton Well, were sampled (see Figure 2-8). Four monitoring wells were sampled during the second round; these included all the new monitoring wells and existing monitoring well CSB-1. Newly installed monitoring wells were sampled no sooner than 14 days after completion of well development.

All wells were purged before sampling using dedicated submersible Whale pumps or dedicated Teflon bailers to help confirm that sampled water was representative of formation water. Before purging, total VOCs at the wellhead and in the breathing zone were monitored with a PID. Each well volume of water removed during purging was monitored for specific conductance, temperature, pH, and turbidity. Redox potential was measured at the end of purging. A monitoring well was considered purged when the volume of groundwater removed was equivalent to five well volumes and the monitored parameters varied by less than approximately 10 percent. Monitoring wells CSB-4 and CSB-5 recovered very slowly, and fewer than five well volumes were removed. Patton Well was allowed

to run for at least one hour before it was sampled. All wells were sampled with dedicated Teflon bailers. All sample jars (except VOC vials) were triple rinsed with sample water. Well water was poured directly from bailers into pre-labeled sample jars. In all cases, if VOCs were to be collected, they were collected before all other samples. Samples to be analyzed for dissolved inorganics were collected from the bailer using a peristaltic pump and a 0.45-micron high capacity in-line filter to remove suspended solids.

All samples were analyzed for PAL SVOCs, pesticides and PCBs, explosives, total inorganics, TOC, TSS, TDS, and alkalinity. Fifty percent of the samples were also analyzed for dissolved inorganics. In addition to the above analytes, samples collected from Patton Well were also analyzed for VOCs.

2.2.8 Fish Sampling and Analysis

Fish sampling at Cold Spring Brook Pond was conducted on October 23, 1992. Electrofishing was the sole technique used to characterize the fish community at this site. Electrofishing consisted of sweeping the sampling region with a boat-mounted Coffelt VVP-15 electroshocking unit. This electrofishing unit was operated in an AC mode with 230 volts and 4 to 7 amperes. Only day electrofishing was conducted at Cold Spring Brook Pond.

Because the pond is shallow and weedy, the only portion of Cold Spring Brook Pond where fish samples were collected was in the channel in the vicinity of the culvert draining the eastern portion of Cold Spring Brook Pond into Cold Spring Brook (see Figure 2-8).

All fish collected were identified to species, weighed to the nearest gram, and measured to the nearest millimeter. Individual fish were checked for external pathological gross abnormalities (e.g., tumors, lesions, structural or bone defects) through an evaluation of the conditions of the lips, jaws, barbels (when applicable), eyes, right gill, fins, urogenital cavity, anus, body form, and body surfaces. All data were recorded on field data sheets. The results of the pathological evaluation of Cold Spring Brook Pond fish are presented in Section 7.0.

Fish species that commonly occur in warmwater ponds in Massachusetts were chosen as the Cold Spring Brook Pond target species for tissue analysis. Target

species were chosen based upon the following criteria: human fishery utilization, abundance, size, ecological importance, position in food chain, and metabolism (USEPA, 1989f). To achieve SAP objectives (ABB-ES, 1992a), the ability to collect sufficient, duplicate, replicate, and/or laboratory QC samples was also considered when selecting target species.

The following species were selected as target species:

- Yellow Bullhead (*Ictalurus natalis*)

  Bullheads are omnivorous bottom feeders of recreational importance. Bullheads are caught for human consumption, and are abundant in warm, shallow ponds of southern New England. During colder months, bullheads are known to bury themselves in muddy pond bottoms, where they remain until warmer months (Werner, 1980). Because of their considerable exposure to pond sediments, bullheads are an ideal organism for tissue contaminant burden analysis.

- Chain pickerel (*Esox niger*)

  This popular game fish feeds on invertebrates and other fish, and is typically found near aquatic vegetation. It was selected for tissue analysis at Cold Spring Brook Pond because it was the top predator documented in the pond.

- Pumpkinseed (*Lepomis gibbosus*)

  Pumpkinseed were sampled to represent a secondary consumer of recreational importance. They are primarily residents of ponds and lakes, but may also occur in quiet waters in streams and rivers. They feed on insects, other invertebrates, mollusks, and an occasional small fish (Werner, 1980).

To avoid field contamination, target species were processed minimally in the field and prepared for shipment to the analytical laboratory. Individual fish were weighed to the nearest gram, measured to the nearest millimeter, and a complete external examination of the fish was recorded on field fish health forms. Each individual fish was assigned a unique numerical identification code that identified

the fish by water body and served to identify the animal from all others captured for analysis. No fish were filleted in the field.

Fish were placed in sealed bags and labeled according to the SAP (ABB-ES, 1992a). All fish were delivered on ice to the analytical laboratory within 24 to 36 hours, via overnight courier. Once in the analytical laboratory, all samples were logged into the laboratory sample management program.

Bullhead and chain pickerel were skinned and filleted in the laboratory using a Teflon-coated stainless steel microtome blade. To obtain sufficient tissue for chemical analysis, fillets from Cold Spring Brook Pond bullhead and pickerel were obtained from both sides of individual fish. In contrast to Plow Shop Pond, "whole fish" analyzed at Cold Spring Brook Pond were entire individual fish, rather than a fish minus one fillet. The skinless fillets and the whole fish were labeled and frozen until analysis. Because no analysis of sunfish (pumpkinseed) fillets was conducted (whole body analysis only), whole fish were frozen immediately upon arrival at the laboratory. All fish remained frozen until laboratory analysis was conducted.

To avoid contamination from inorganics associated with stainless steel laboratory instrumentation, whole fish were macerated in a tissue homogenizer with a titanium blade. Whole fish and fillets were analyzed for 22 PAL inorganics, pesticides and PCBs, lipids, and percent solids. Inorganics were analyzed in accordance with USEPA Method 600/4-81/055. Organic analyses were completed as detailed in the SAP (ABB-ES, 1992a).

Comparisons of the analytical data to state and national data are provided in Appendix N, and Appendix T contains summary tables of analytical data.

2.2.9 Macroinvertebrate Sampling

A semiquantitative inventory of macroinvertebrates was conducted at three sampling stations in Cold Spring Brook Pond (see Figure 2-8). At each sampling station, two duplicate macroinvertebrate samples from vegetation ("phytomacrofauna") and two duplicate samples from sediment ("benthic infauna") were collected. In siting the individual sampling stations, an attempt was made to confirm that the stations were as comparable as possible with respect to water movement, substrate composition, canopy coverage, and water depth. All

macroinvertebrate samples were collected in September 1992, and processed as described in Subsection 2.1.11 for Plow Shop Pond macroinvertebrates.

Information regarding the physical attributes of the aquatic habitat (including nature of the substrate and vegetative characteristics) and water quality parameters (i.e., dissolved oxygen, temperature, pH, and conductivity) was also collected at each sampling station.

Appendix P contains the results of the macroinvertebrate analyses.

2.2.10 Wetland Functional Assessment

A WET evaluation was conducted on Cold Spring Brook Pond to assess the functions and values of this wetland. WET is a standardized evaluation technique that provides a rapid assessment of many of the recognized values and functions of a wetland (Adamus et al., 1991). WET uses a standardized manual and answer sheet to provide input data for the WET 2.0 computer program. After data are entered into the WET program, a "Low," "Medium," or "High" value is assigned to each function.

A combination of the following 11 functions (i.e., physical, , and biological characteristics) and values (characteristics beneficial to society) were evaluated through WET at Cold Spring Brook Pond:

- Groundwater Recharge
- Groundwater Discharge
- Floodflow Alteration
- Sediment Stabilization
- Sediment/Toxicant Retention
- Nutrient Removal/Transformation
- Production Export
- Wildlife Diversity/Abundance
- Aquatic Diversity/Abundance
- Uniqueness/Heritage
- Recreation

The above-listed functions and values were evaluated by WET in the following contexts: "Social Significance" (the value of the wetland to society); "Effectiveness"

(the capability of the wetland to provide the function); and "Opportunity" (the opportunity of the wetland to provide the function).

The WET analysis determined that the value to society of Cold Spring Brook Pond is "high" for Wildlife Diversity and Abundance, as well as for Uniqueness and Heritage. The remainder of the evaluated WET parameters were rated "low" in social significance. In terms of effectiveness, WET scored Cold Spring Brook Pond as "high" for Sediment/Toxicant Retention, Nutrient Removal/ Transformation, and Wildlife Breeding and Migration, and as "moderate" for Groundwater Discharge, Floodflow Alteration, and Production Export. The effectiveness of Cold Spring Brook Pond to provide several other functions and values was rated as "low" by WET. Of the three functions/values evaluated for Opportunity, the opportunity for Cold Spring Pond to perform the Sediment/ Toxicant Retention and Nutrient Removal/Transformation functions is rated as "high" by WET. Cold Spring Pond has the opportunity to provide these functions because of the proximity of the adjacent landfill. Floodflow Alteration is rated as "moderate" by WET based upon the high percentage of the watershed this wetland occupies.

The WET functional assessment is included as Appendix O. In addition, this appendix includes a detailed narrative discussion interpreting the results of the WET analysis.

2.3 Field Investigation Program at Grove Pond

Surface water and sediment samples were collected from five predesignated locations along the western side of Grove Pond (Figure 2-9). Each sample location was given two site IDs, GRW-92-01X/GRD-92-01X, GRW-92-02X/ GRD-92-02X, GRW-92-03X/GRD-92-03X, GRW-92-04X/GRD-92-04X, and GRW-92-05X/GRD-92-05X. The first site ID was for the surface water sample and the second for the sediment.

The surface water samples were collected in the following manner: total VOCs were monitored by PID above the surface water, and temperature, pH, and specific conductance were monitored in situ. Prior to sample collection, all water sample jars (except VOC vials) were triple rinsed with sample water. The appropriate pre-labeled sample jars were then filled by direct immersion

immediately below the surface of the water. Water samples were preserved in the field in accordance with the requirements of the POP (ABB-ES, 1992b) and stored on ice in coolers prior to and during shipment to the laboratory. All surface water samples were analyzed for PAL VOCs, SVOCs, pesticides and PCBs, total inorganics, TOC, TSS, TDS, and alkalinity.

Upon completion of surface water sampling, a sediment sample was collected from the water sediment interface at the same location as the surface water sample. Samples were collected with either a hand auger or an Ekman dredge and placed in pre-labeled sample jars. All sampling equipment was decontaminated prior to use at each sample location. Sediment samples were stored on ice in coolers before shipment to the laboratory. Reference samples were sent to the laboratory to be tested for grain-size distribution. All sediment samples were analyzed for PAL VOCs, SVOCs, pesticides and PCBs, total inorganics, and TOC. Results of grain-size distribution analyses are summarized in Table 2-11. Complete results of grain-size analyses are provided in Appendix D.

2.4 Field Investigation Program at New Cranberry Pond

2.4.1 Macroinvertebrate Sampling

A semiquantitative inventory of macroinvertebrates was conducted at three sampling stations in New Cranberry Pond (Figure 2-10). New Cranberry Pond served as the "reference station" for macroinvertebrate samples collected from Plow Shop Pond and Cold Spring Brook Pond. At each sampling station, two duplicate macroinvertebrate samples from vegetation ("phytomacrofauna") and two duplicate samples from sediment ("benthic infauna") were collected. In siting the individual sampling stations, an attempt was made to confirm that the stations were as comparable as possible with respect to water movement, substrate composition, canopy coverage, and water depth. All macroinvertebrate samples were collected in September 1992, and processed as described in Subsection 2.1.11.

Information regarding the physical attributes of the aquatic habitat (including nature of the substrate and vegetative characteristics) and water quality

parameters (i.e., dissolved oxygen, temperature, pH, and conductivity) was also collected at each sampling station.

Appendix P contains the results of the macroinvertebrate analyses.

2.4.2 Sediment Sampling

One shallow sediment sample was collected at each of the three macroinvertebrate sampling stations in New Cranberry Pond to document sediment characteristics (see Figure 2-10). Sampling locations were given the site IDs CRD-92-01X, CRD-92-02X, and CRD-92-03X. Samples were collected from the water sediment interface with a hand auger and placed in pre-labeled sample jars. All sampling equipment was decontaminated before use at each sample location. Sediment samples were stored on ice in coolers prior to shipment to the laboratory. All sediment samples were tested for PAL VOCs, SVOCs, pesticides and PCBs, explosives, total inorganics, and TOC. Complete results of grain-size analyses are provided in Appendix D.

2.5 ANALYTICAL PROGRAM

Analytical samples were collected from surface soil, subsurface soil, groundwater, surface water, and sediment and submitted for laboratory analyses to identify contaminants that were expected, based on available information about conditions and operations, to be encountered at Shepley's Hill and Cold Spring Brook Landfills. The program included an extensive range of organic and inorganic analytes. The specific analyses performed on samples are discussed in Subsection 2.5.1 of this report.

2.5.1 Analytical Parameters

Soil, sediment, and groundwater samples were analyzed for Fort Devens PAL analytes. Laboratory analyses for the PAL organics, inorganics, and explosives are similar to USEPA analytical support Level III quality data (Contract Laboratory Program [CLP] Routine Analytical Services [RAS]). The Fort Devens PAL is presented in Appendix G.

The primary laboratory used for the Delivery Order 0004 analytical program was Environmental Science and Engineering, Inc. (ESE) of Gainesville, Florida, an USAEC-approved laboratory.

A list of USAEC performance demonstrated methods used for analyses of PAL analytes in samples collected during the Group 1A supplemental field investigation is provided in Table 2-12. The table includes a description of the methods used as well as equivalent USEPA methods where they exist. The method numbers (e.g., method JS16) are specific to the project and to the particular laboratory performing the analyses.

2.5.2 Quality Assurance/Quality Control

All water and soil environmental samples collected from the Shepley's Hill Landfill at Fort Devens Army Base were submitted to a USAEC Contractor Laboratory. The laboratory used for this project was ESE Laboratories, Gainesville, Florida. Laboratories performing this work must effectively implement the USAEC QA Program (USATHAMA, 1990).

2.5.2.1 Laboratory Certification. In accordance with the QA Program, laboratories must demonstrate proficiency in conducting chemical analysis for specific analytes. Analytical methods are listed with a brief description in Table H9 of Appendix H. Laboratories gain approval by first submitting data from runs of calibration standards. Performance samples are then sent for analysis to the laboratory from USAEC. The concentrations of the analytes in these samples are unknown by the laboratory. The performance data are then sent to USAEC where the precision and accuracy of the analyses are determined. Approval is either awarded to or denied the laboratory based on this performance. A method code is assigned to each method and reported with results.

Some methods such as alkalinity, TOC and TSS do not require performance demonstration. USAEC recognizes standard USEPA protocols or internal laboratory methods for these parameters. Laboratories are required to submit information on procedures for analyzing samples using these methods to the USAEC Chemistry Branch before they are implemented.

2.5.2.2 Laboratory Methods Quality Control. The laboratory organizes all submitted samples into lots which are assigned a three or four digit code using letters of the alphabet. Each lot consists of the maximum number of samples, including QC samples that can be processed through the rate limiting step of the method during a single time period (not exceeding 24 hours). Lots may consist of samples from multiple installations provided the data quality objectives are the same. The rate limiting step is usually determined by time or equipment limitations.

Associated with each lot are laboratory control samples. Control samples are spikes of both high and low concentration of specific analytes that help monitor laboratory precision and accuracy. The recoveries of these spikes are plotted on control charts generated by the laboratory and submitted to USAEC. Data generated from the certification process are used to calculate a mean of the recoveries. Control and warning limits are statistically generated by the USAEC Chemistry Branch to help measure laboratory data quality. Certified Reporting Limits (CRLs) are also determined from this process. CRLs for each particular analyte are listed in Tables H-10 through H-16 of Appendix H.

Method blanks are also run at the laboratory to evaluate the potential for target analytes to be introduced during the processing and analysis of samples. One method blank is included in each analytical lot. Method blank results are found in Tables H-7 and H-24 of Appendix H.

2.5.2.3 Data Reduction and Evaluation. Initial responsibility for accuracy and completeness of data packages rests with the laboratory itself. All data submissions to USAEC must first undergo a review process. This review includes checks on the data quality which evaluate completeness of laboratory data, accuracy of reporting limits, compliance with quality control limits and holding times, and correlation of laboratory data to associated laboratory tests.

The following items are also reviewed before being submitted to USAEC:

- Chain of custody records.
- Instrument printouts to see if these agree with handwritten results.

- Calibration records to ensure a particular lot is associated with only on calibration.
- Chromatograms and explanations for operator corrective actions (such as manual integrations).
- Standard preparation and documentation of source.
- Calculations on selected samples.
- Notebooks and sheets of paper to ensure all pages are dated and initialed, and explanations of procedure changes.
- GC/MS library search of unknown compounds.
- Transfer files and records to ensure agreement with analysis results.

To document the data review and evaluation process a data review checklist is submitted as part of the data package.

2.5.2.4 Data Reporting. Once the data have undergone review and evaluation by the laboratory they are encoded for transmission into USAEC's IRDMIS (Installation Restoration Data Management Information System) as Level 1 data. Once into the system the data are subjected to a group and records check.

Data are then transferred to an army data management contractor. During this phase the data are considered to be "Level 2." Another group and records check is performed and data are reviewed by the USAEC Chemistry Branch. If errors are identified the data are returned to the laboratory for correction. Once data have been reviewed by the USAEC Chemistry Branch the determination is made on a lot by lot basis whether the data are acceptable. The data that are accepted are then elevated to Level 3. The data is available to USAEC personnel and contractors by modem to a main frame computer. Appendix U is a computer diskette that contains Level 3 data files for samples collected during Data Gap Activities at Group 1A sites.

2.5.2.5 Field Quality Control Samples. Quality control samples collected in the field include matrix spikes, matrix spike duplicates, rinsate blanks, trip blanks, a field blank, and duplicate samples.

Matrix spikes and matrix spike duplicates (MS/MSDs) were collected at a rate of one set per twenty samples. Site investigators made the determination of which samples were to be designated as MS/MSDs. This was noted on the chain of custody forms submitted to the laboratory. The samples designated as MS/MSDs were spiked at the laboratory with target analytes to see what matrix effects may have occurred on the target analytes. MS/MSD results are presented in Appendix H.

Duplicate samples were collected at the same rate as MS/MSDs. The samples were submitted to the laboratory to be analyzed for the same chemicals as the corresponding primary samples. The purpose of submitting these samples is to assess laboratory precision for a particular method. Duplicate sample results are presented in Appendix H.

At the beginning of the site investigation a sample of USAEC approved water was collected. This was identified as the field blank. The information gained from the analysis of this blank provides data on the quality of the USAEC approved water used in the decontamination of the sampling equipment. Field blank information can be used to explain the presence of certain analytes or compounds in the rinsate blanks. A field blank collected in the spring of 1993 was analyzed to make this determination. Field blank results are summarized by method in Appendix H.

Rinsate blanks were collected and analyzed for VOCs, SVOCs, inorganics, pesticides/PCBs, explosives and other methodologies including alkalinity, hardness, TDS, TOC and TSS. They were collected by running laboratory "chemically pure" deionized water through the sampling apparatus that was used to collect the samples. Analysis of this water provides information used to evaluate the potential for sample contamination during sample collection. The results determine also whether an adequate job is being done during the decontamination of the equipment. Rinsate blanks were collected at a rate of one per twenty samples per decontamination event.

For every shipment of VOA samples sent to the laboratory, there is an accompanying pair of trip blanks that travel with the samples. A trip blank is a VOA sample container previously filled at the laboratory with chemically pure water. Once the trip blanks are received back, they are analyzed for VOCs to determine whether there is cross contamination during shipment.

2.5.2.6 Analytical Data Quality Evaluation. Group 1A laboratory data collected during the 1992-1993 sampling at Fort Devens were evaluated for possible laboratory or sampling-related contamination. This evaluation did not include validation by USEPA guidelines. Sample results were not adjusted for reported analytes that were also detected at similar concentrations in blanks associated with that sample. Action levels were not established and the 10X rule was not applied to compounds considered to be common laboratory contaminants as defined by the USEPA. These contaminants include the VOCs acetone, methylene chloride, toluene and SVOC phthalate esters (i.e. bis (2-Ethylhexyl) phthalate). Action levels for other analytes using the 5X rule application were not established. Analytes which would have been below these action levels were not removed from the data as they would be in the USEPA validation process. All data appears as it was reported. None of the data has been rejected and removed.

General trends relating to blank and sample contamination were examined. Comparison of blank data with results from the entire data set are discussed as a data assessment. Assessments are made based on analyte detection in blanks, the frequency of this detection and the concentrations of these analytes. These assessments are made in Appendix H.

2.6 CHEMICAL DATA MANAGEMENT

Chemical data were managed by ABB-ES' Sample Management System and the USAEC's IRDMIS. These systems are described in the following subsections.

2.6.1 Sample Tracking System

ABB-ES employed its computerized Sample Management System to track environmental samples from field collection to shipment to the laboratory. ABB-ES also tracked the status of analyses and reporting by the laboratory.

Each day, the field sampling teams carried computer-generated sample labels into the field that stated the sample control number, sample identification, size and type of container, sample preservation summary, analysis method code, and sample medium. The labels also provided space for sampling date and time and the collector's initials to be added at the time of collection.

Samples were temporarily stored in the ABB-ES field office refrigerator. They were checked-in on the computer, and the collector's initials and the sampling date and time were entered. The system would then indicate the sample status as "COLLECTION IN PROGRESS."

When the samples were prepared for shipment, they were "RELEASED" by the sample management system. Upon request, the system printed an Analysis Request Form and a COC form , which were signed and included with the samples in the shipment. The system would then indicate the sample status as "SENT TO LAB."

This system substantially reduced the time required for preparation of sample tracking documentation, and it provided an automated record of sample status.

After shipment of samples to the laboratory, ABB-ES continued to track and record the status of the samples, including the date analyzed (to establish actual holding times), the date a transfer file was established by ESE, and the date the data were sent to IRDMIS (see Subsection 2.6.2)

2.6.2 Installation Restoration Data Management Information System

IRDMIS is an integrated system for collection, validation, storage, retrieval, and presentation of data of the USAEC's Installation Restoration and Base Closure Program. It uses personal computers (PCs), a UNIX-based minicomputer, printers, plotters, and communications networks to link these devices.

For each sample lot, ABB-ES developed a "provisional" map file for the sample locations, which was entered into IRDMIS by PRI, USAEC's data management contractor.

Following analysis of the sample lot, ESE created chemical files using data codes provided by ABB-ES, and entered the analytical results (Level 1) on a PC in

accordance with the User's Manual (PRI, 1993). For each sample lot, a hard copy was printed which was reviewed and checked by ESE's Laboratory Program Manager. ESE created a transfer file from accepted records that was sent to ABB-ES (Level 2). ABB-ES performed a group and record check and sent approved records in a chemical transfer file to PRI. PRI checked the data and, if accepted, entered it into the IRDMIS minicomputer (Level 3). Level 3 chemical data are the data used for evaluating site conditions and are the data used in reports and decision-making.

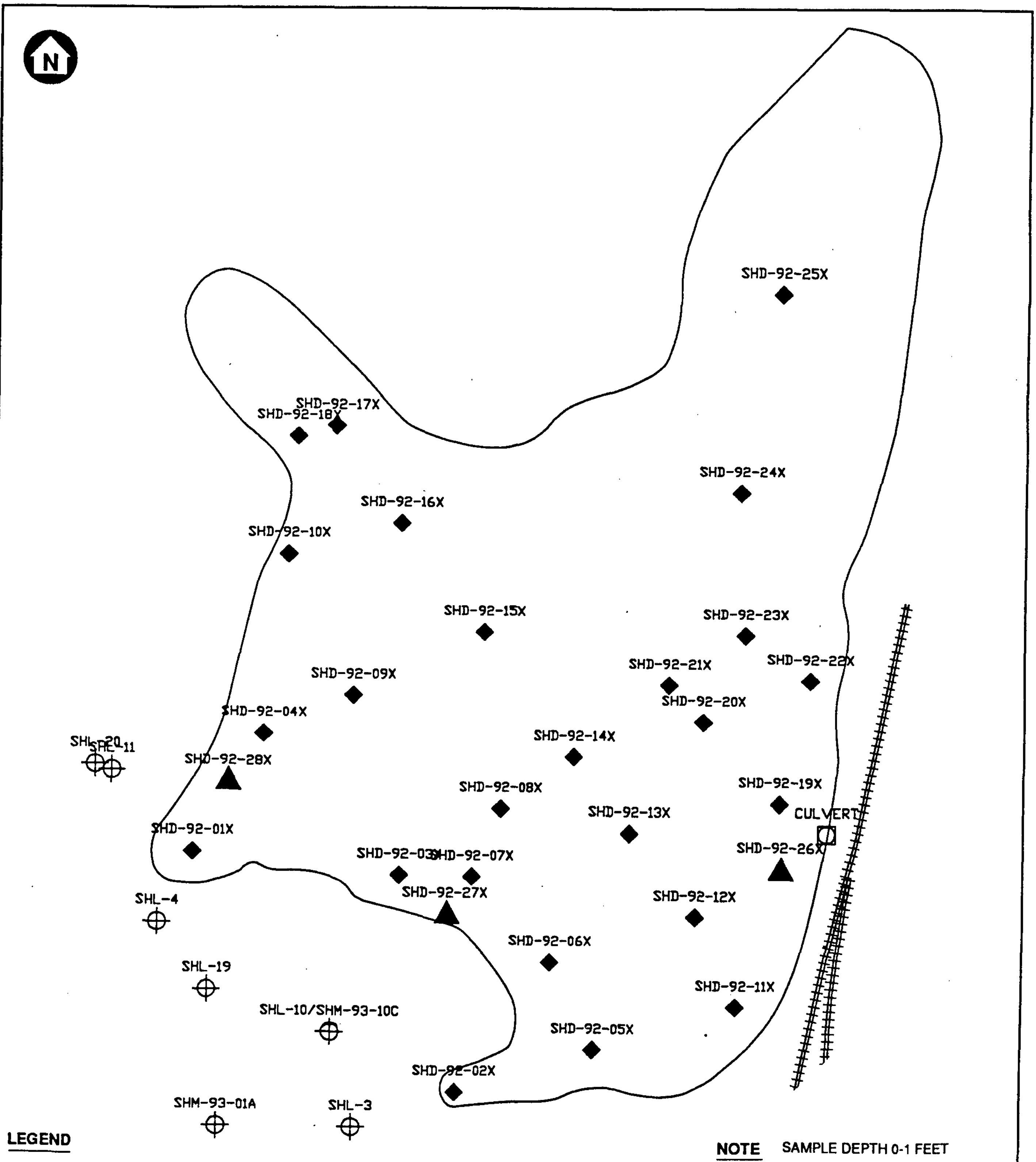
2.7 Investigation Derived Waste

Wastes were generated in association with personal protection, drilling, monitoring well construction and development, sampling, and decontamination.

Soil brought to the ground surface by drilling was segregated into piles for each 5-foot depth. A soil headspace PID measurement was taken from each pile in accordance with the POP. All piles had headspace measurements at background concentrations and were discarded at the drilling locations.

Drilling water circulated back to the ground surface, well development purge water, and decontamination fluids were collected in drums. A headspace measurement was made by PID on water from each drum. All drums had headspace values at background concentrations and were discharged at the point of collection.

All pre-sampling purge water was discharged at the point of collection.



NOTE SAMPLE DEPTH 0-1 FEET

LEGEND

◆ VIBROCORE SEDIMENT SAMPLE LOCATION

▲ MACROINVERTEBRATE/SEDIMENT CHARACTERIZATION SAMPLES

⊕ MONITORING WELLS

SCALE IN FEET

0 250 500

FIGURE 2-1
SEDIMENT SAMPLING LOCATIONS
PLOW SHOP POND
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

9307007D

ABB Environmental Services, Inc.

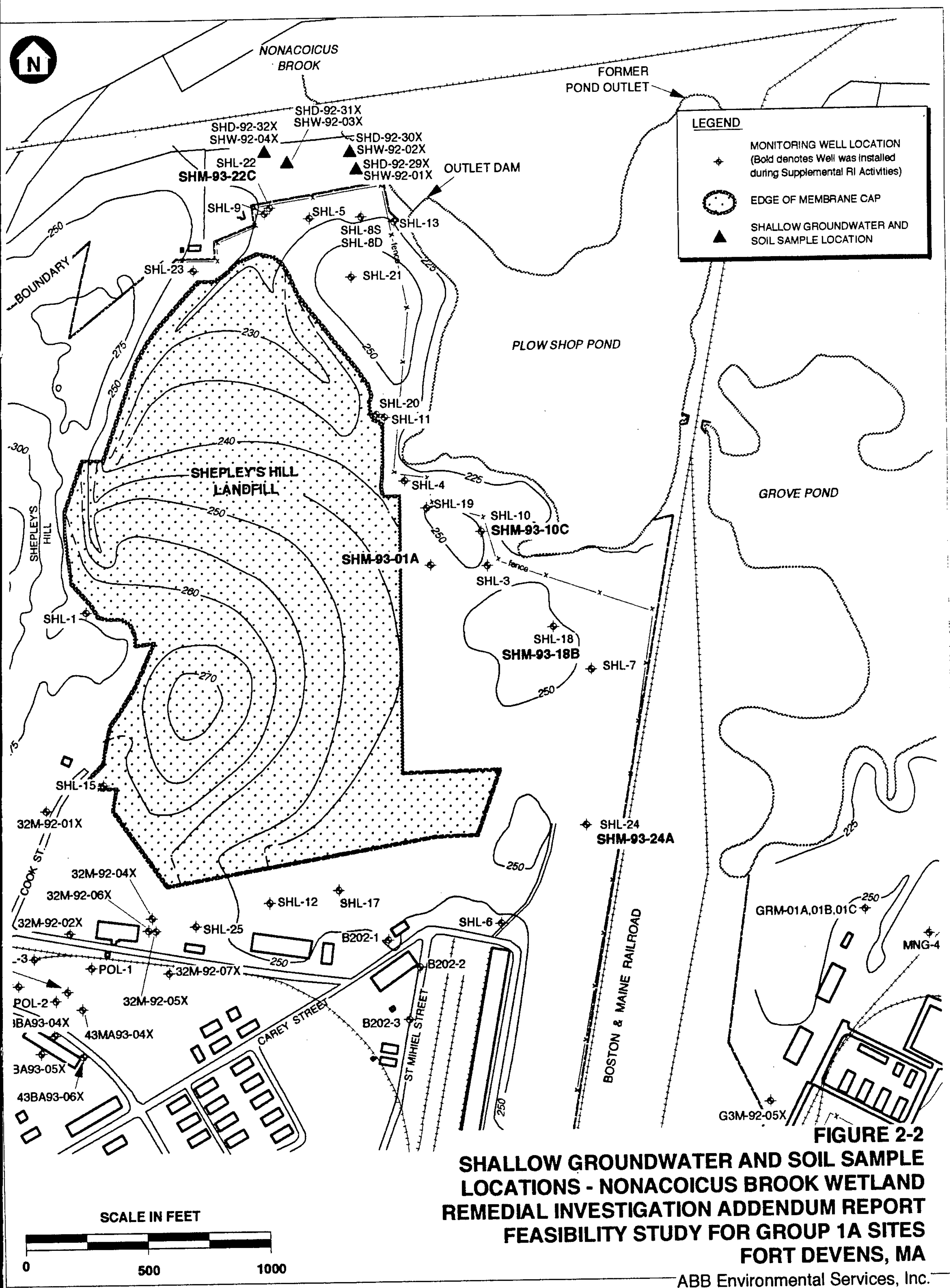


FIGURE 2-2
SHALLOW GROUNDWATER AND SOIL SAMPLE LOCATIONS - NONACOICUS BROOK WETLAND
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9303022D 1S6N

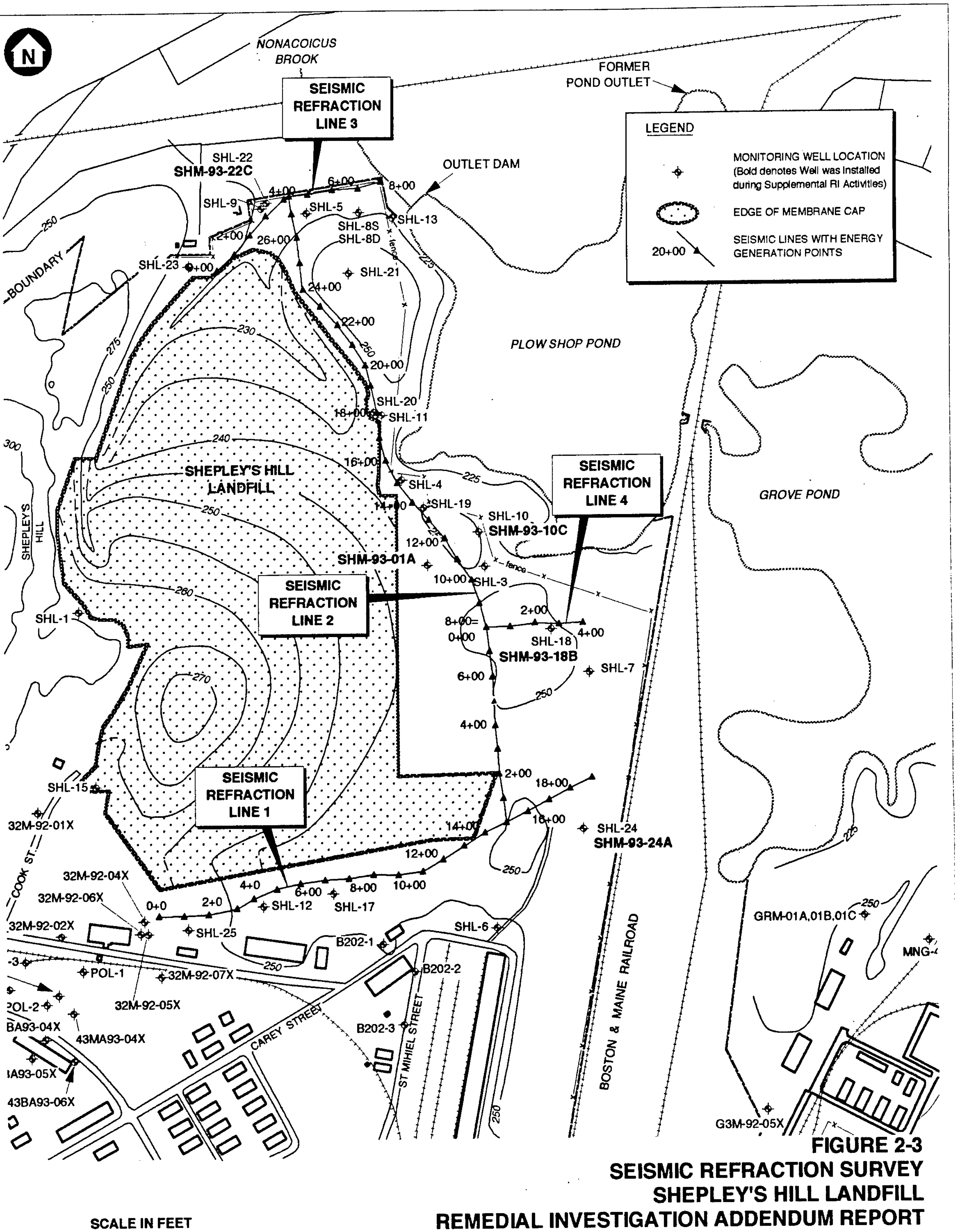
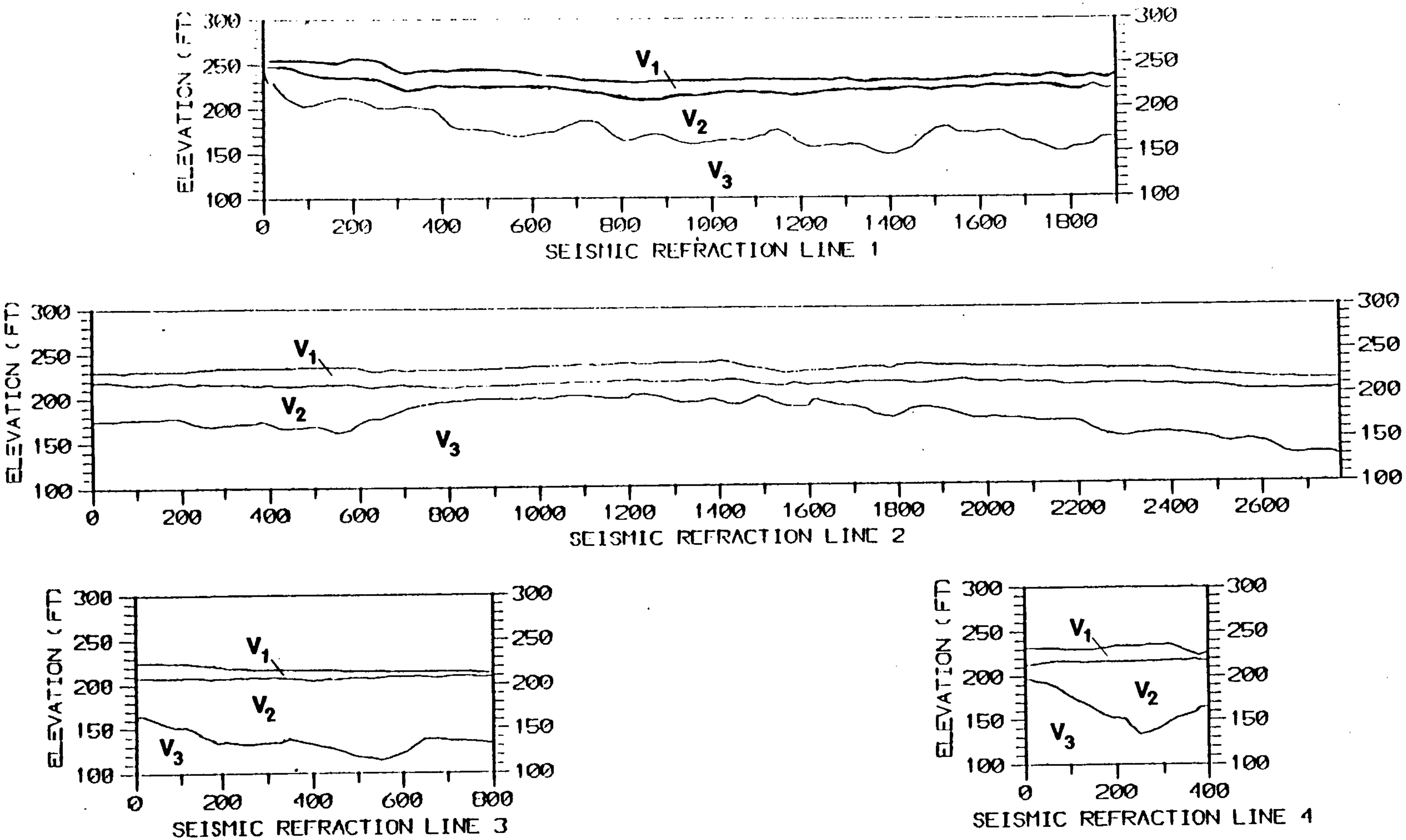


FIGURE 2-3
SEISMIC REFRACTION SURVEY
SHEPLEY'S HILL LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9303022D 1S67J



LEGEND

V1 - 800 TO 1,600 fps. LOOSE, UNCONSOLIDATED AND UNSATURATED OVERBURDEN.

V2 - 4,000 TO 5,200 fps. SATURATED, UNCONSOLIDATED OVERBURDEN.

V3 - 12,000 TO 18,000 fps. BEDROCK, HIGHER VALUES MAY INDICATE RELATIVELY MORE COMPETENT ZONES; LOWER VALUE MAY INDICATE WEATHERED AND/OR FRACTURED ZONES

NOTES

1. GROUND SURFACE IS FROM SURVEY DATA PROVIDED BY HOWE SURVEYING ASSOCIATES, NO. CHELMSFORD, MA.

2. SEISMIC VELOCITY VALUES ARE IN FEET PER SECOND.

3. DASHED LINES INDICATE SOME UNCERTAINTY IN THE INTERPRETATION OF SEISMIC DATA.

4. VERTICAL EXAGGERATION IS 2:1.

FIGURE 2-4
SEISMIC REFRACTION PROFILES
SHEPLEY'S HILL LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FT. DEVENS, MA

ABB Environmental Services, Inc.

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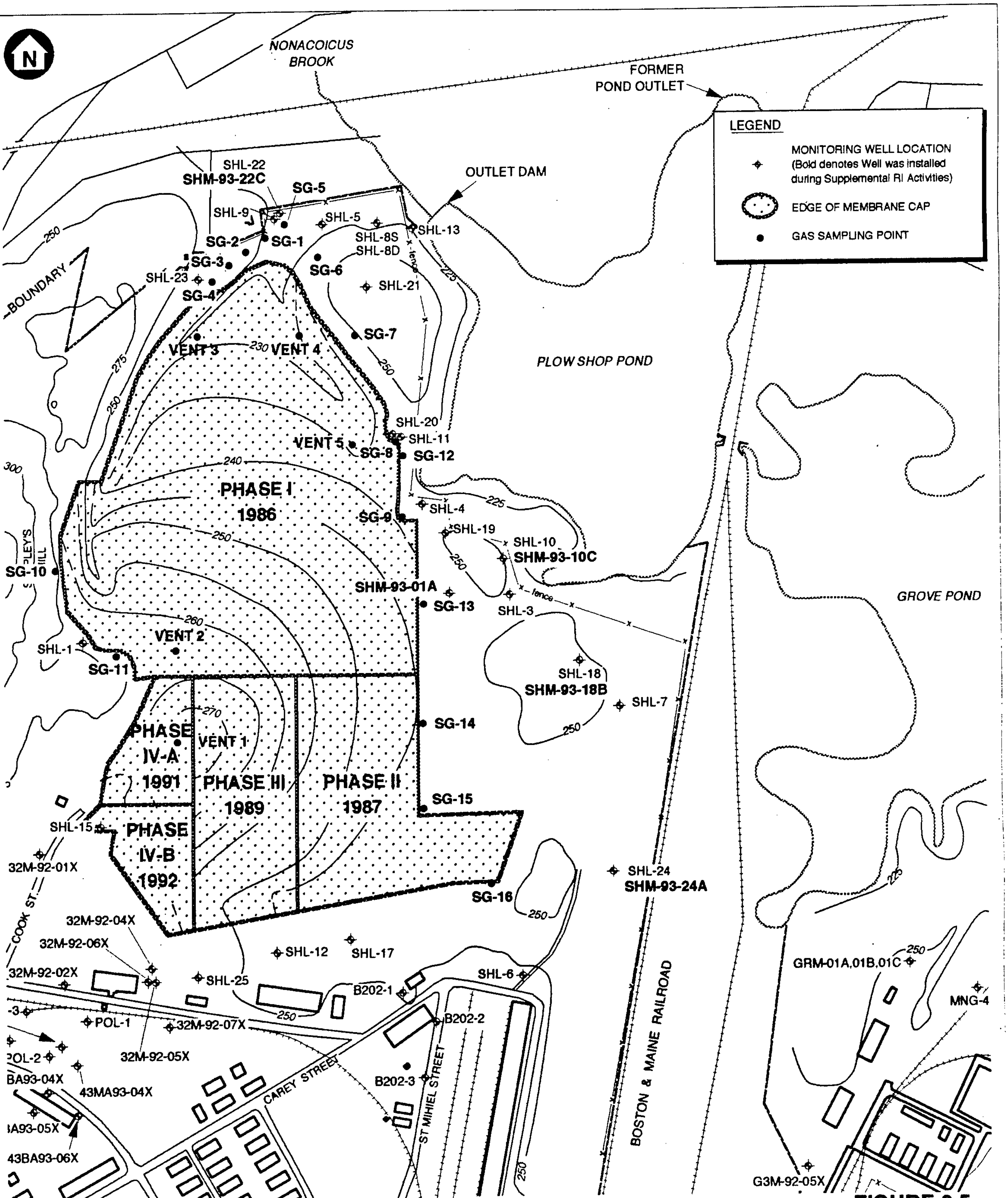

FIGURE 2-5
LANDFILL GAS MONITORING LOCATIONS
SHEPLEY'S HILL LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9303022D 1SEC6

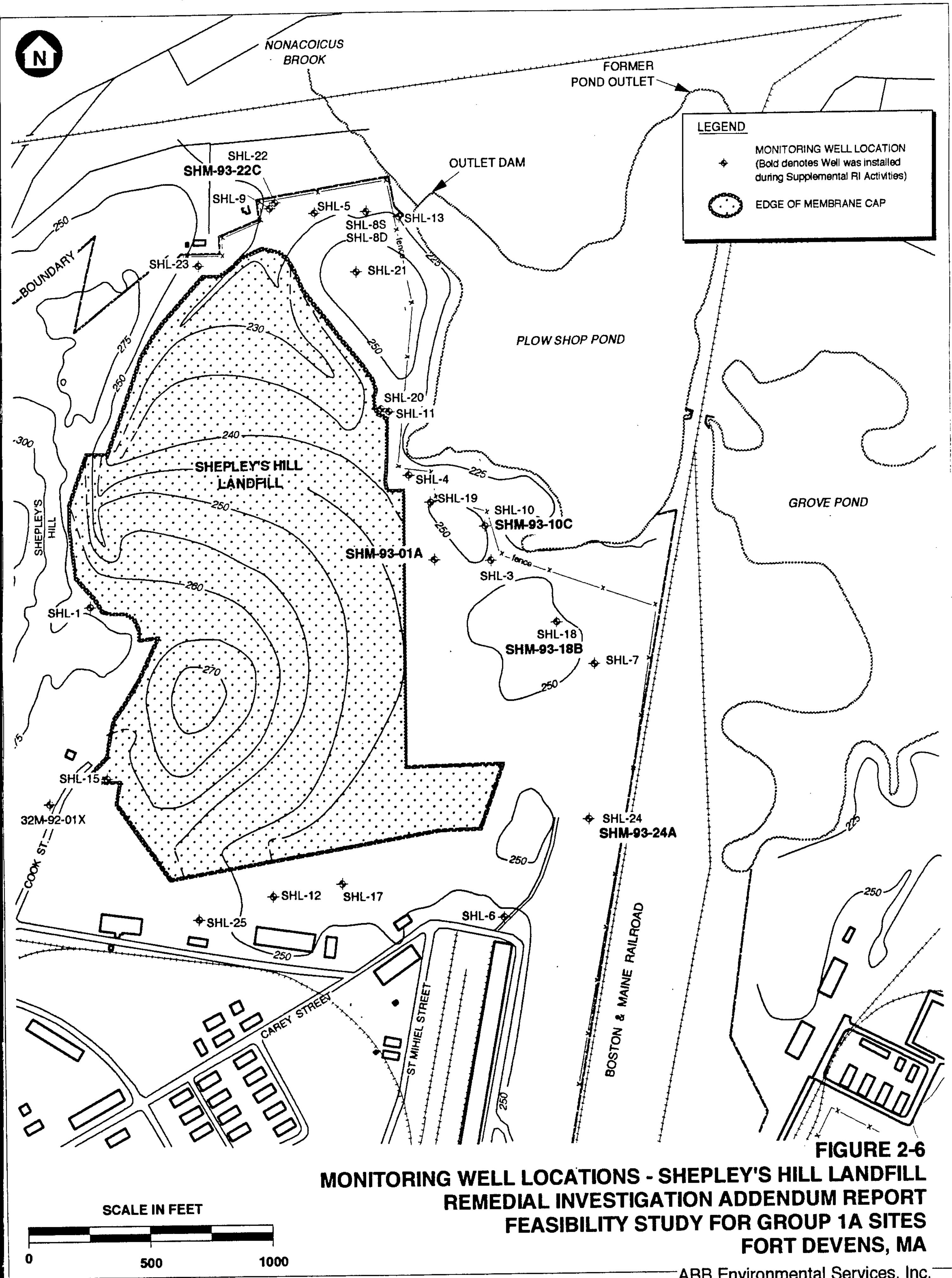

FIGURE 2-6
MONITORING WELL LOCATIONS - SHEPLEY'S HILL LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9303022D 1ST

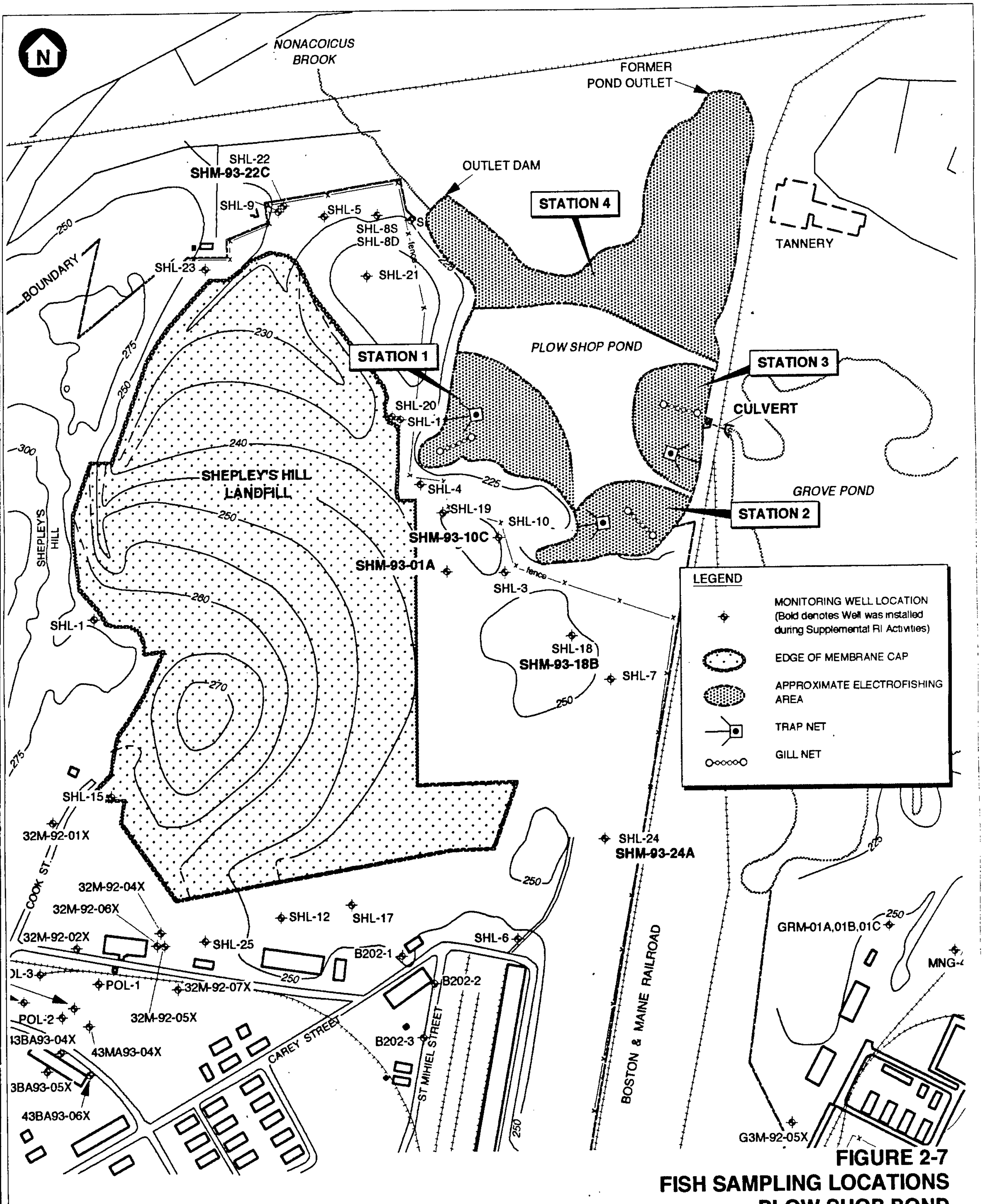

FIGURE 2-7
FISH SAMPLING LOCATIONS
PLOW SHOP POND
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9303022D 1S6U

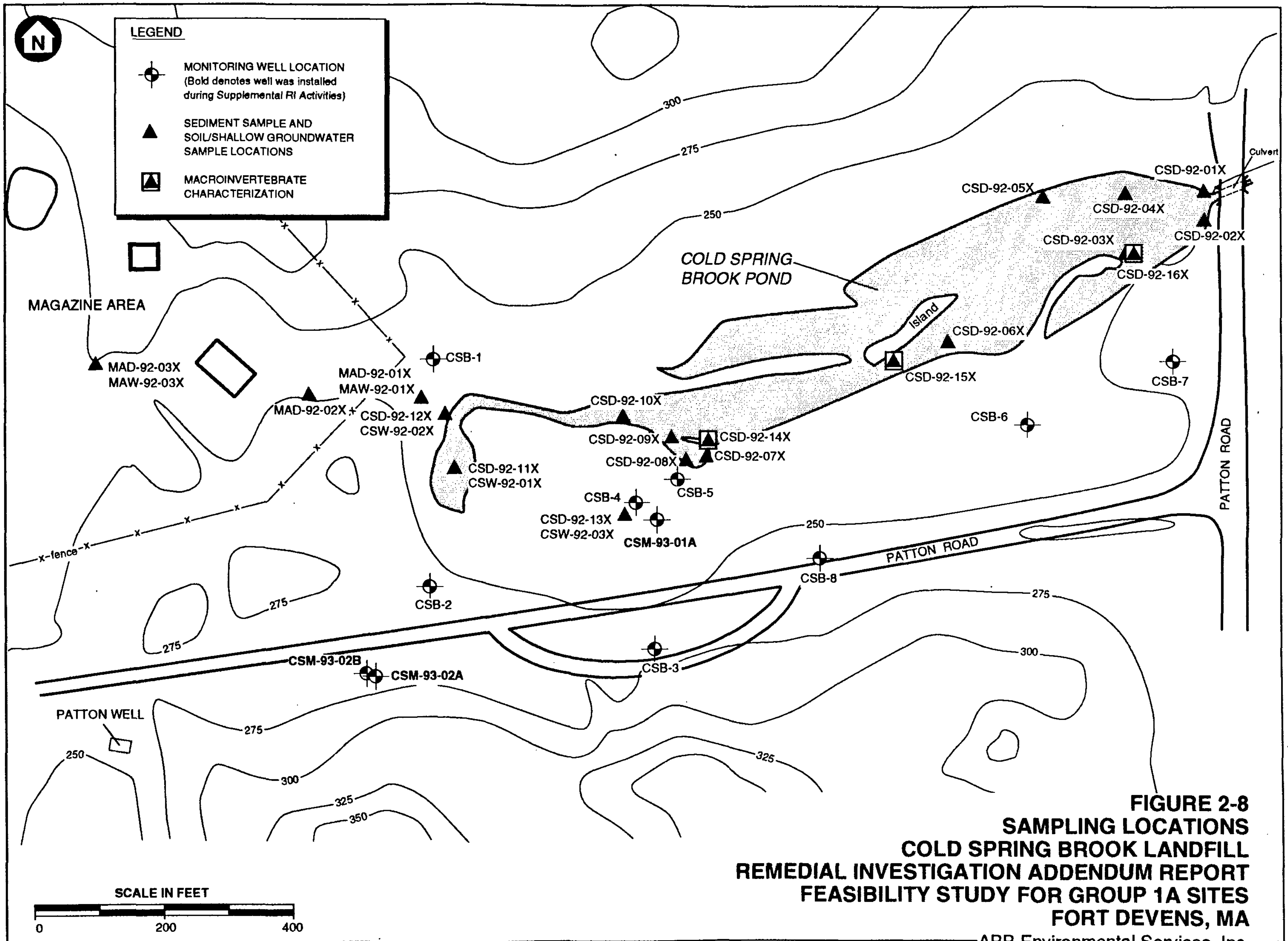

FIGURE 2-8
SAMPLING LOCATIONS
COLD SPRING BROOK LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9305033D 234 9

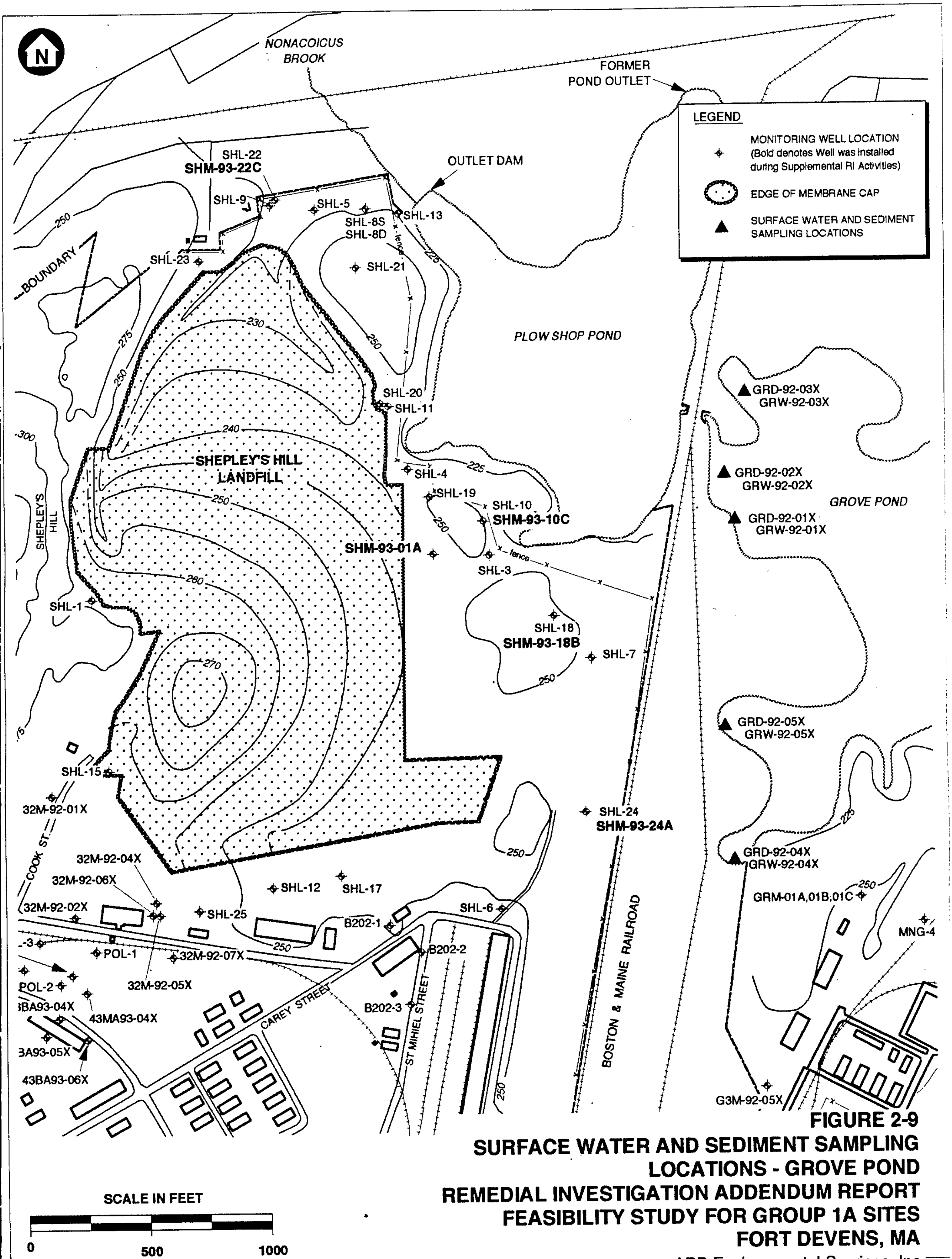

FIGURE 2-9
SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS - GROVE POND
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9303022D 1S6AA

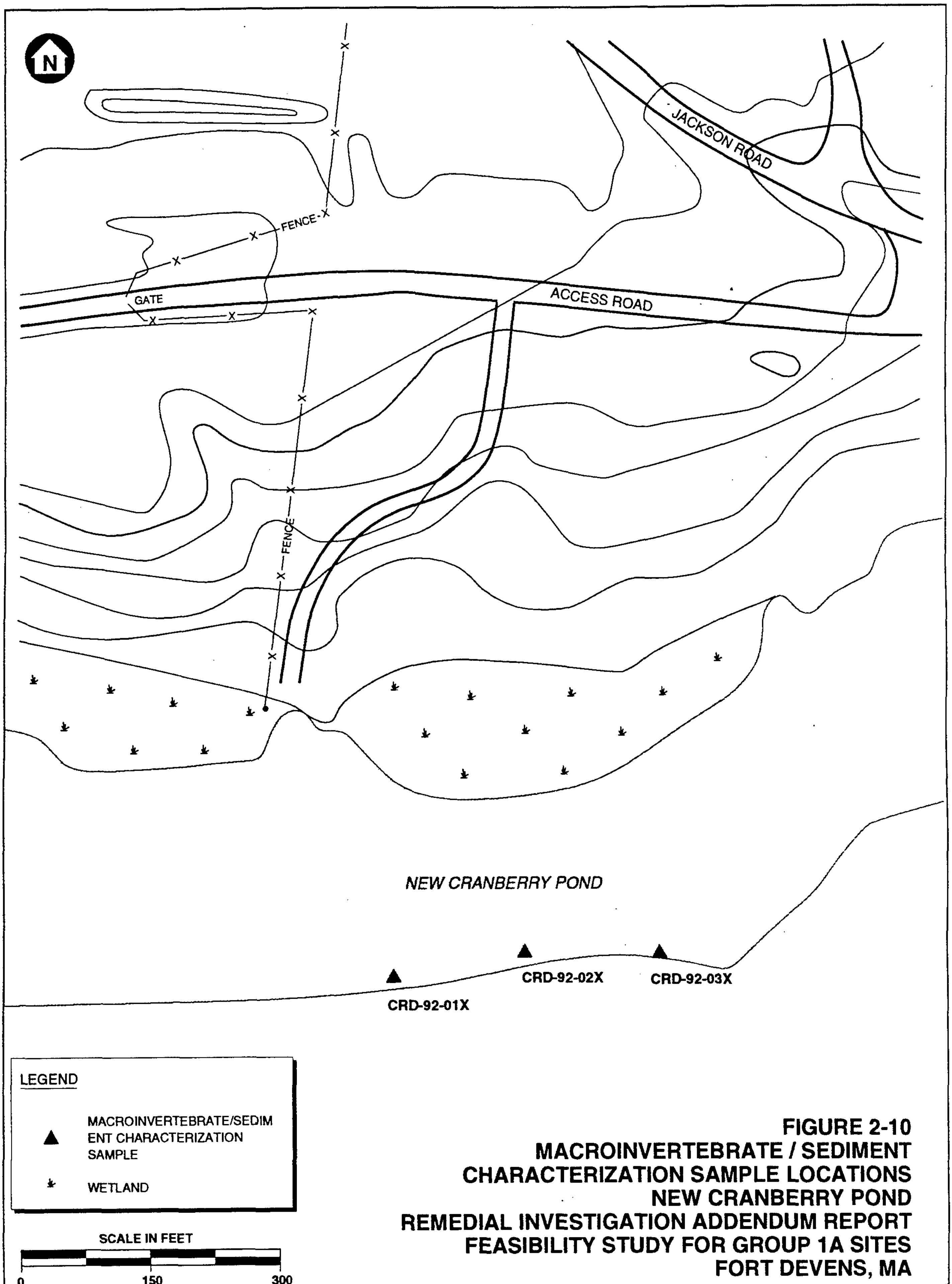

FIGURE 2-10
MACROINVERTEBRATE / SEDIMENT CHARACTERIZATION SAMPLE LOCATIONS
NEW CRANBERRY POND
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9306037D 1

TABLE 2-1
SOIL CLASSIFICATION OF SEDIMENT SAMPLES
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE ID	SAMPLE DEPTH	USCS SYMBOL[1]	GRAVEL[2] DRY WT %	SAND[2] DRY WT %	FINES[2] DRY WT %	COMMENTS
SHD-92-01X	0	PT				Sample could not be tested due to high organic content
SHD-92-01X	3	PT	0	38	62	
SHD-92-01X	5	SW	0	98	2	
SHD-92-02X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-03X	0	PT				Sample could not be tested due to high organic content
SHD-92-04X	1	PT				Sample could not be tested due to high organic content
SHD-92-05X	0-4	PT				Sample could not be tested due to high organic content
SHD-92-06X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-07X	0-3	PT				Sample could not be tested due to high organic content
SHD-92-08X	0-7	PT				Sample could not be tested due to high organic content
SHD-92-09X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-10X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-11X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-12X	0-3	PT				Sample could not be tested due to high organic content
SHD-92-12X	4	PT	0	83	18	
SHD-92-13X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-14X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-15X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-16X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-17X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-18X	0-3	PT				Sample could not be tested due to high organic content
SHD-92-18X	5	PT-SW	4	91	5	
SHD-92-19X	0	PT	8	87	5	
SHD-92-19X	2	GW	36	64	0	Not large enough to be representative of particle size
SHD-92-20X	0-5	PT-SW				Sample could not be tested due to high organic content
SHD-92-21X	0-7	PT				Sample could not be tested due to high organic content
SHD-92-22X	0-3	PT				Sample could not be tested due to high organic content
SHD-92-23X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-24X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-25X	0-5	PT				Sample could not be tested due to high organic content
SHD-92-26X	0	SW-GW	55	42	3	Not large enough to be representative of particle size

TABLE 2-1
SOIL CLASSIFICATION OF SEDIMENT SAMPLES
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE ID	SAMPLE DEPTH	USCS SYMBOL[1]	GRAVEL[2] DRY WT %	SAND[2] DRY WT %	FINES[2] DRY WT %	COMMENTS
SHD-92-27X	0	SP	2	93	5	
SHD-92-28X	0	SP-SM	1	92	7	

Notes:
USCS = Unified soil classification system
DRY WT % = Dry weight percentage
[1] In absence of grain size distribution analyses USCS classifications were determined from field data
[2] Weight percentage of soil fraction = 100 x dry weight of soil fraction/total dry weight of soil
GW = well graded gravel
PT = peat
SM = silty sand to sandy silt
SP = poorly graded sand
SW = well graded sand

TABLE 2-2
CLASSIFICATION OF SOIL SAMPLES
NONACOICUS BROOK

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE ID	SAMPLE DEPTH	USCS[1] SYMBOL	GRAVEL[2] DRY WT %	SAND[2] DRY WT %	FINES[2] DRY WT %	COMMENTS
SHD-92-29X	0	SP-SM	0	76	24	Not large enough to be representative of particle size
SHD-92-29X	2	SW-GW	24	69	7	
SHD-92-30X	0	SW-SM	2	68	10	
SHD-92-30X	2	SW	11	81	7	
SHD-92-31X	0	SM	1	24	75	
SHD-92-31X	1	SP-SM	2	76	23	
SHD-92-32X	0					Sample not received by lab
SHD-92-32X	1	SM	0	68	32	

Notes:
USCS = Unified soil classification system
DRY WT % = Dry weight percentage
[1] In absence of grain size distribution analyses USCS classifications were determined from field data
[2] Weight percentage of soil fraction = 100 x dry weight of soil fraction/total dry weight of soil
SM = silty sand to sandy silt
SP = poorly graded sand
SW = well graded sand

TABLE 2-3
SUMMARY OF SOIL BORINGS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPLORATION ID	COMPLETION DEPTH (Feet bgs)	REFERENCE SAMPLE INTERVALS (Feet bgs)	ANALYTICAL SAMPLES COLLECTED	SOIL TYPE[1] (USCS)	TOTAL VOCs BY PID (ppm)	COMMENTS
SHM-93-01A	26	0-2		SP	BKG	
		5-7		SP	BKG	
		10-12		SP	BKG	
		15-17	20-22	SP-SW	BKG	
		20-22		SP	BKG	
		25-25.5		SP-SM	BKG	
SHM-93-10C	36.5	0-2		SP	BKG	
		5-7		SP	BKG	
		10-12		SP	BKG	
		15-17		SP	BKG	
		20-22		SP	BKG	
		25-27		SP	BKG	
		30-32		SP-SM	BKG	
		35-36.5		SP-SM	BKG	
SHM-93-18B	93.5	0-2		SP	BKG	
		5-7		SP	BKG	
		10-12		SP-SM	BKG	
		15-17		SW-SM TO SP	BKG	
		20-22		SP	BKG	
		25-27		SP	BKG	
		30-32		SP	BKG	
		33-37		SP	BKG	
		40-42		SP	BKG	
		45-47		SP	BKG	
		50-52			BKG	soils ran out of spoon when retrieved
		55-57			BKG	soils ran out of spoon when retrieved
		58-60			BKG	no recovery - sands ran out of spoon
		69-71		SP	BKG	
		74-76		SP	BKG	
		78-80		SW-SP	BKG	
		83-85		SP	BKG	
		88-90	88-90	SP	BKG	

TABLE 2-3
SUMMARY OF SOIL BORINGS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPLORATION ID	COMPLETION DEPTH (Feet bgs)	REFERENCE SAMPLE INTERVALS (Feet bgs)	ANALYTICAL SAMPLES COLLECTED	SOIL TYPE[1] (USCS)	TOTAL VOCs BY PID (ppm)	COMMENTS
SHM-93-22C	135					no split-spoons collected (see soil boring log for SHL-22 installed by Ecology and Environment)
SHM-93-24A	24	0-2		SW	BKG	
		5-7		SW	BKG	
		10-12		SP	BKG	
		15-17	15-17	SP	BKG	
		20-22		SP	BKG	
SHB-93-01X	25	0-5		SM	BKG	
		5-10		SP-SM	BKG	
		10-15		SP-SM	BKG	
		15-20		SP-SM	BKG	
		20-25		SP-SM	BKG	
		25-26		SP-SM	BKG	

Notes:
bgs = below background surface
VOCs = Volatile organic compound
USCS = Unified soil classification system
[1] USCS classifications determined from boring logs
ppm = parts per million
SM = silty sand to sandy silt
SP = poorly graded sand
SW = well graded sand
BKG = Total VOCs by PID equivalent to or below background levels.
Total VOCs were measured with a PID in ambient air periodically during the course of work.

TABLE 2-4
MONITORING WELL COMPLETION DETAILS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

WELL IDENTIFICATION	SOIL DRILLING METHOD	BEDROCK DRILLING METHOD	MEDIA SCREENED (USCS)	WELL SCREEN DEPTH (Feet bgs)	WELL SCREEN ELEVATION (Feet NGVD)	COMPLETION DEPTH (Feet bgs)	CONSTRUCTION MATERIAL (SCH 40 PVC)
SHM-93-01A	HOLLOW STEM AUGER	NA	SP-SW	15.5-25.5	226.2-216.2	26	4" ID PVC
SHM-93-10C	DRIVE AND WASH	CORE AND OVERREAM	ROCK	44-54	203.1-193.1	59.5	4" ID PVC
SHM-93-18B	DRIVE AND WASH/ HOLLOW STEM AUGER	NA	SP-SW	78.5-88.5	157.7-147.7	93.5	4" ID PVC
SHM-93-22C	DRIVE AND WASH	CORE AND OVERREAM	ROCK	124.3-134.3	93.6-83.6	134.9	4" ID PVC
SHM-93-24A	HOLLOW STEM AUGER	NA	SP	13.2-23.2	222.3-212.3	24	4" ID PVC

Notes:
bgs = below ground surface
ID = inside diameter
NA = not applicable
NGVD = National Geodetic Vertical Datum
PVC = polyvinyl chloride
SCH = schedule
SP = poorly graded sand
SW = well graded sand
USCS = Unified Soil Classification System

TABLE 2-5
SUMMARY OF WATER LEVELS AND HYDRAULIC CONDUCTIVITIES
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

WELL ID	ELEVATION[1]	DEPTH TO WATER[2] (From pvc)	ELEVATION OF WATER (Feet NGVD)	HYDRAULIC CONDUCTIVITY	
				HVORSLEV[3] (cm/sec)	BOUWER & RICE[3] (cm/sec)
SHM-93-01A	243.4	21.24	220.6	1.4E-03	7E-03
SHM-93-10C	248.79	29.79	218.32	2.9E-05	2E-04
SHM-93-18B	238.38	18.47	218.78	5.4E-04	4E-03
SHM-93-22C	219.76	6.64	211.41	4.9E-08	6E-06
SHM-93-24A	237.53	15.42	220.49	1.6E-02	4E-02

Notes:
bgs = below ground surface
cm/sec = centimeters per second
NGVD = National Geodetic Vertical Datum
1 = elevation of pvc
2 = measurements collected on June 21, 1993
3 = averaged value of two tests

TABLE 2–6

SOIL CLASSIFICATION OF SEDIMENT SAMPLES
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE ID	SAMPLE DEPTH	USCS[1] SYMBOL	GRAVEL[2] DRY WT %	SAND[2] DRY WT %	FINES[2] DRY WT %	COMMENTS
CSD–92–01X	0	PT				Sample could not be tested due to high organic content
CSD–92–01X	2	SW	13	83	4	
CSD–92–01X	3	SM–SW	1	91	9	
CSD–92–02X	0	PT				Sample could not be tested due to high organic content
CSD–92–02X	2	SP	4	92	5	
CSD–92–02X	4	SP	2	96	3	
CSD–92–03X	0	PT	1	81	18	
CSD–92–03X	3	SM	1	84	15	
CSD–92–03X	5	SM	0	30	70	
CSD–92–04X	0	SP–SM–PT	12	80	9	not large enough to be representative of particle size
CSD–92–04X	3	SP–SM	0	83	17	
CSD–92–04X	5	SM	0	29	71	
CSD–92–05X	0	PT–SM	0	80	20	
CSD–92–05X	2	SP	0	94	6	
CSD–92–05X	4	SM	0	31	69	
CSD–92–06X	0	PT–SM–SP	0	77	23	
CSD–92–06X	2	SM	2	76	22	
CSD–92–06X	4	SM	0	32	68	
CSD–92–07X	0–2	PT				Sample could not be tested due to high organic content
CSD–92–08X	0–2	PT				Sample could not be tested due to high organic content
CSD–92–09X	0–5	PT–SP–SM				Sample could not be tested due to high organic content
CSD–92–10X	0	SP–SM	0	81	20	
CSD–92–10X	2	SP	7	82	11	
CSD–92–11X	0	SM				Sample could not be tested due to high organic content
CSD–92–12X	0	SM	0	30	70	
CSD–92–13X	0	SM	0	75	25	

Notes:
USCS = Unified soil classification system
DRY WT % = Dry weight percentage
[1] In absence of grain size distribution analyses USCS classifications were determined from field data
[2] Weight percentage of soil fraction = 100 x dry weight of soil fraction/total dry weight of soil
PT = peat
SM = silty sand to sandy silt
SP = poorly graded sand
SW = well graded sand

TABLE 2-7
CLASSIFICATION OF SOIL SAMPLES
MAGAZINE AREA (ASP)

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE ID	SAMPLE DEPTH	USCS SYMBOL[1]	GRAVEL[2] DRY WT %	SAND[2] DRY WT %	FINES[2] DRY WT %	COMMENTS
MAD-92-01X	0	PT				Sample could not be tested due to high organic content
MAD-92-02X	0	SW-SM	34	54	12	
MAD-92-03X	0	PT				Sample could not be tested due to high organic content

Notes:
USCS = Unified soil classification system
DRY WT % = Dry weight percentage
[1] In absence of grain size distribution analyses USCS classifications were determined from field data
[2] Weight percentage of soil fraction = 100 x dry weight of soil fraction/total dry weight of soil
PT = peat
SM = silty sand to sandy silt
SP = poorly graded sand
ASP = Ammunition Supply Program

TABLE 2-8
SUMMARY OF SOIL BORINGS
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPLORATION ID	COMPLETION DEPTH (Feet bgs)	REFERENCE SAMPLE INTERVALS (Feet bgs)	ANALYTICAL SAMPLES COLLECTED	SOIL TYPE (USCS)	TOTAL VOCs BY PID (ppm)	COMMENTS
CSM-93-01A	65.5	15-16		GM	BKG	
		22-24		SW	BKG	
		24-26		SW	BKG	
		28-30	28-30	SW	BKG	some granite
		34.5-36.5		PT	BKG	and brick in wash
		36.5-38.5		PT	BKG	
		42.5-44.5		SM	BKG	some wood in wash
		49-51		SM	BKG	
		51-53		SW	BKG	
		59-61		SP-SM	BKG	
		65.5-67.5		SP-SM	BKG	
CSM-93-02A	129.6	10-12		SP	BKG	
		15-17		SP	BKG	
		20-22		SP	BKG	
		25-27	25-27	SW	BKG	
		30-32		SW	BKG	
		35-37		SW	BKG	
		40-42		SP-SM	BKG	
		45-47		SP-SM	BKG	no sample taken - due to flowing sands
		50-52		SP	BKG	
		55-57	55-57	SW	BKG	
		60-62		SW	BKG	
		65-67		SW	BKG	no sample taken - due to flowing sands
		70-72		SW	BKG	no sample taken - due to flowing sands
		75-77		SW	BKG	no sample taken - due to flowing sands

TABLE 2-8
SUMMARY OF SOIL BORINGS
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPLORATION ID	COMPLETION DEPTH (Feet bgs)	REFERENCE SAMPLE INTERVALS (Feet bgs)	ANALYTICAL SAMPLES COLLECTED	SOIL TYPE (USCS)	TOTAL VOCs BY PID (ppm)	COMMENTS
		80-82		SW	BKG	
		85-87		SW	BKG	no recovery - material in spoon appears to be wash
		90-92		SW	BKG	
		95-97		SW	BKG	
		100-102		SW	BKG	
		105-107		SP	BKG	
		110-112		SW-GW	BKG	
		115-117		SW	BKG	
		120-122		SW	BKG	no recovery
		125-127		SW	BKG	
		129		SW-GW	BKG	
CSM-93-02B	68				BKG	no soil samples collected - monitoring well installation

Notes:
bgs = below background surface
GM = medium graded gravel
GW = well graded gravel
PT = peat
ppm = parts per million
SM = silty sand to sandy silt
SP = poorly graded sand
SW = well graded sand
USCS = Unified soil classification system
VOCs = Volatile organic compounds
BKG = Total VOCs by PID equivalent to or below background levels.
Total VOCs were measured with a PID in ambient air periodically during the course of work.

TABLE 2-9
MONITORING WELL COMPLETION DETAILS
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

WELL IDENTIFICATION	SOIL DRILLING METHOD	BEDROCK DRILLING METHOD	MEDIA SCREENED (USCS)	WELL SCREEN DEPTH (Feet bgs)	WELL SCREEN ELEVATION (Feet NGVD)	COMPLETION DEPTH (Feet bgs)	CONSTRUCTION MATERIAL (SCH 40 PVC)
CSM-93-01A	DRIVE AND WASH	NA	SW-SP-SM	53.6-63.6	201.3-191.3	65.5	4" ID PVC
CSM-93-02A	HOLLOW STEM AUGER	NA	SP-SW	21.5-31.5	241.2-231.2	33	4" ID PVC
CSM-93-02B	HOLLOW STEM AUGER	NA	SW	57-67	205.5-195.5	68	4" ID PVC

Notes:
bgs = below ground surface
ID = inside diameter
NA = not applicable
NGVD = National Geodetic Vertical Datum
PVC = polyvinyl chloride
SCH = schedule
SM = silty sand to sandy silt
SP = poorly graded sand
SW = well graded sand
USCS = Unified Soil Classification System

TABLE 2-10
SUMMARY OF WATER LEVELS AND HYDRAULIC CONDUCTIVITIES
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

WELL ID	ELEVATION[1]	DEPTH TO WATER[2] (From pvc)	ELEVATION OF WATER (Feet NGVD)	HYDRAULIC CONDUCTIVITY	
				HVORSLEV[3] (cm/sec)	BOUWER & RICE[3] (cm/sec)
CSM-93-01A	256.18	15.99	240.62	4.6E-04	6E-03
CSM-93-02A	264.82	24.64	240.09	8.2E-04	2E-03
CSM-93-02B	264.09	24.42	240.1	2.7E-03	1E-02

Notes:
bgs = below ground surface
cm/sec = centimeters per second
NGVD = National Geodetic Vertical Datum
1 = elevation of pvc
2 = measurements collected on June 21, 1993
3 = averaged value of two tests

TABLE 2-11
SOIL CLASSIFICATION OF SEDIMENT SAMPLES
GROVE POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE ID	SAMPLE DEPTH	USCS SYMBOL[1]	GRAVEL[2] DRY WT %	SAND[2] DRY WT %	FINES[2] DRY WT %	COMMENTS
GRD-92-01X	0	SM	1	72	27	
GRD-92-02X	0					No sample supplied to lab for grain size analysis
GRD-92-03X	0					No sample supplied to lab for grain size analysis
GRD-92-04X	0	GW-SW	28	65	7	not large enough to be representative of particle size
GRD-92-05X	0					sample could not be tested due to high organic content

Notes:
USCS = Unified soil classification system
DRY WT % = Dry weight percentage
[1] In absence of grain size distribution analyses USCS classifications were determined from field data
[2] Weight percentage of soil fraction = 100 x dry weight of soil fraction/total dry weight of soil
SM = silty sand to sandy silt
SW = well graded sand
GW = well graded gravel

TABLE 2-12
AEC CERTIFIED METHODS AND USEPA EQUIVALENTS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

AEC METHOD NUMBER	COMPARABLE USEPA METHOD NUMBER	METHOD DESCRIPTION
JB01	7471	Mercury in Soil by CVAA.
JD15	7740	Selenium in Soil by GFAA.
JD16	7911	Vanadium in Soil by GFAA.
JD17	7421	Lead in Soil by GFAA.
JD18	7761	Silver in Soil by GFAA.
JD19	7060	Arsenic in Soil by GFAA.
JS16	6010	Metals in Soil by ICP.
LH10	8080	Organochlorine Pesticides in Soil by GC-EC.
LH11	8150	Herbicides in Soil by GC-EC.
LH16	8080	PCBs in Soil by GC-EC.
LM18	8270	Extractable Organics in Soil by GC/MS.
LM19	8240	Volatile Organics in Soil by GC/MS.
LW12	8090	Nitroaromatics in Soil by HPLC.
SB01	245.1	Mercury in Water by CVAA.
SD20	239.2	Lead in Water by GFAA.
SD21	270.2	Selenium in Water by GFAA.
SD22	206.2	Arsenic in Water by GFAA.
SD23	272.2	Silver in Water by GFAA.
SS10	200.7	Metals in Water by ICAP.
TF22	300.0	Nitrate/Nitrite in Water by Auto Analyzer.
TF26	351.2	TKN in Water by Autoanalyzer.
TF27	365.1	Total Phosphate in Water by Autoanalyzer.
TT10	300.0	Anions in Water by IC.
UH02	608	PCBs in Water by GC.
UH13	608	Organochlorine Pesticides in Water by GC.
UH14	615	Herbicides in Water by HPLC.
UM18	625	Extractable Organics in Water by GC/MS.
UM20	624	Volatiles in Water by GC/MS.
UW19		PETN/Nitroglycerin in Water.
UW32	609	Nitroaromatics in Water by HPLC.

3.0 PHYSICAL CHARACTERISTICS

The climate, vegetation, ecology, physiography, soils, surficial and bedrock geology, and regional hydrogeology of Fort Devens are described in the subsections that follow.

Fort Devens is located in the towns of Ayer and Shirley (Middlesex County) and Harvard and Lancaster (Worcester County), approximately 35 miles northwest of Boston, Massachusetts. It lies within the Ayer, Shirley, and Clinton map quadrangles (7½-minute series). The installation occupies approximately 9,260 acres and is divided into the North Post, the Main Post, and the South Post (Figure 3-1).

More than 6,000 acres at Fort Devens are used for training and military maneuvers, and more than 3,000 acres are developed for housing, buildings, and other facilities; the installation has been reported as the largest undeveloped land holding under a single owner in north-central Massachusetts (USFWS, 1992).

The South Post is located south of Massachusetts Route 2 and is largely undeveloped. The Main Post and North Post primarily contain developed lands, including recreational areas (e.g., a golf course and Mirror Lake), training areas, and an airfield. Group 1A sites are located on the main post.

The following subsections describe the history and physical setting of Fort Devens.

3.1 HISTORY

Camp Devens was created as a temporary cantonment in 1917 for training soldiers from the New England area. It was named after Charles Devens - a Massachusetts Brevet Major General in the Union Army during the Civil War who later became Attorney General under President Rutherford Hayes. Camp Devens, served as a reception center for selectees, as a training facility, and, at the end of World War I, as a demobilization center (Marcoa Publishing Inc., 1990). At Camp Devens the 1918 outbreak of Spanish influenza infected 14,000 people, killed 800, and caused the installation to be quarantined (McMaster et al., 1982). Peak military strength during World War I was 38,000. After World

War II, Fort Devens became an installation of the U.S. Army Field Forces, CONARC in 1962 and the U.S. Army Forces Command (FORSCOM) in 1973 (Biang et al., 1992).

In 1921, Camp Devens was placed in caretaker status. During summers from 1922 to 1931, it was used as a training camp for National Guard troops, Reserve units, Reserve Officer Training Corps (ROTC) cadets, and the Civilian Military Training Corps (CMTC). In 1929, Dr. Robert Goddard used Camp Devens to test his early liquid-fuel rockets, and there is a monument to him on Sheridan Road near Jackson Gate (Fort Devens Dispatch, 1992).

In 1931, troops were again garrisoned at Camp Devens. It was declared a permanent installation, and in 1932 it was formally dedicated as Fort Devens. During the 1930s, there was a limited building program, and beautification projects were conducted by the Works Progress Administration (WPA) and Civilian Conservation Corps (CCC).

In 1940, Fort Devens became a reception center for New England draftees, and was expanded to more than 10,000 acres. Approximately 1,200 wooden buildings were constructed, and two 1,200-bed hospitals were built. In 1941, the Army Airfield was constructed by the WPA in of 113 days (Fort Devens Dispatch, 1992). In 1942, the Whittemore Service Command Base Shop for motor vehicle repair (Building 3713) was built, and at the time it was known as the largest garage in the world (U.S. Army, 1979). The installation's current wastewater treatment plant was also constructed in 1942 (Biang et al., 1992).

During World War II, more than 614,000 inductees were processed. Fort Devens' population reached a peak of 65,000. Three Army divisions and the Fourth Women's Army Corps trained at Fort Devens, and it was the location of the Army's Chaplain School, the Cook & Baker School, and a basic training center for Army nurses. A prisoner-of-war camp for 5,000 German and Italian soldiers was operated from 1944 to 1946. At the end of the war, Fort Devens again became a demobilization center, and in 1946 it reverted to caretaker status.

Fort Devens was reactivated in July 1948 and again became a reception center during the Korean Conflict. It has been an active Army facility since that time.

Currently, the mission at Fort Devens is to command and train its assigned duty units; operate the South Boston Support Activity in Boston; the Sudbury Training Annex and the Hingham USAR Annex; and to support the 10th Special Forces Group (A), the U.S. Army Intelligence School, Fort Devens; the U.S. Army Reserves; Massachusetts Army National Guard; and ROTC Training Programs. No major industrial operations occur at Fort Devens, although several small-scale industrial operations are performed under (1) the Directorate of Plans, Training, and Security; (2) the Directorate of Logistics; and (3) the Directorate of Engineering and Housing. The major waste-producing operations by these groups are photographic processing and maintenance of vehicles, aircraft, and small engines. Past artillery fire, mortar fire, and waste explosive disposal at Fort Devens are potential sources for explosives contamination (USAEC, 1993).

Under Public Law 101-510, the Base Closure and Realignment Act (BRAC) of 1990, Fort Devens has been identified for closure by July 1997, and 4,600 acres are to be retained to establish a Reserve Component enclave and regional training center.

3.2 Physical Setting

The climate, vegetation, ecology, physiography, soils, surficial and bedrock geology, and regional hydrogeology of Fort Devens are described in the subsections that follow.

3.2.1 Climate

The climate of Fort Devens is typical of the northeastern United States, with long cold winters and short hot summers. Climatological data were reported for Fort Devens by the U.S. Department of the Army (1979), based in part on a 16-year record from Moore Army Airfield (MAAF).

The mean daily minimum temperature in the coldest months (January and February) is 17 degrees Fahrenheit (°F), and the mean daily maximum temperature in the hottest month (July) is 83°F. The average annual temperature is 58°F. There are normally 12 days per year when the temperature reaches or exceeds 90°F and 134 days when it falls to or below freezing.

The average annual rainfall is 39 inches. Mean monthly precipitation varies from a low of 2.3 inches (in June) to a high of 5.5 inches (in September). The average annual snowfall is 65 inches, and snowfall has been recorded in the months of September through May (falling most heavily from December through March).

Wind speed averages 5 miles per hour (mph), ranging from the highest monthly average of 7 mph (March-April) to the lowest monthly average of 4 mph (September).

Average daytime relative humidities range from 71 percent (January) to 91 percent (August), and average nighttime relative humidities range from 46 percent (April) to 60 percent (January).

3.2.2 Vegetation

The Main and North Posts at Fort Devens are characterized primarily by urban and developed cover types. Approximately 56 percent of that area is covered by developed lands, the golf course, the airfield, and the wastewater infiltration beds. Early successional forest cover types (primarily black cherry-aspen hardwoods) encompass approximately 2 percent of the area, mixed oak-red maple hardwoods approximately 20 percent, and white pine-hardwood mixes approximately 11 percent. The rest of the North and Main Posts are characterized by various coniferous species, shrub habitat, and herbaceous cover types.

Much of the South Post is undeveloped forested land. The area includes approximately 8 percent early successional forest (black cherry, red birch, grey birch, quaking aspen, red maple); 26 percent mixed oak hardwoods; and 9 percent coniferous forest (white pine, pitch pine, red pine). Four percent of the area comprises a mixed shrub community. The 200-acre Turner Drop Zone is maintained as a grassland that represents a "prairie" habitat. Vegetative cover in the large "impact area" of the central South Post has not been mapped in detail. It is dominated by fire-tolerant species such as pitch pine and scrub oak.

Extensive sandy glaciofluvial soils are found in the Nashua River Valley, particularly in the South and North Post areas of Fort Devens. Extensive accumulations of these soils are unusual in Massachusetts outside of Cape Cod and adjacent areas of southeastern Massachusetts, and they account for some of the floral and faunal diversity at the installation.

3.2.3 Ecology

Fort Devens encompasses numerous terrestrial, wetland, and aquatic habitats in various successional stages. Floral and faunal diversity is strengthened by the installation's close proximity to the Nashua River; the amount, distribution, and nature of wetlands; and the undeveloped state and size of the South Post (USFWS, 1992). Much of Fort Devens was formerly agricultural land and included pastures, woodlots, orchards, and cropped fields. Existing habitat types reflect this agrarian history, ranging from abandoned agricultural land to secondary growth forested regions. Fort Devens is generally reverting back to a forested state.

There are 1,313 acres of wetlands at Fort Devens. The wetlands are primarily palustrine, although riverine and lacustrine types are also found. Forested palustrine floodplain wetlands associated with the Nashua River and its tributary Nonacoicus Brook are located on Fort Devens' Main and North Posts. These include 191 acres of flooded areas, emergent marsh, and shrub wetlands. Also present are 245 acres of isolated regions of palustrine wetlands and lacustrine systems. On the South Post, there are 877 acres of wetlands, consisting of deciduous forested wetlands, deciduous shrub swamps, emergent marsh, open lacustrine waters in ponds, and open riverine waters (USFWS, 1992).

Approximately half of Fort Devens' land area abuts the northern boundary of the Oxbow National Wildlife Refuge (NWR), a federal resource administered as part of the Great Meadows NWR (USFWS, 1992).

Fort Devens supports an abundance and diversity of wildlife. Identified taxa include 771 vascular plant species, 538 species of butterflies and moths, eight tiger beetle species, 30 vernal pool invertebrates, 15 amphibian species (six salamanders, two toads, seven frogs), 19 reptile species (seven turtles, 12 snakes), 152 bird species, and 42 mammal species. The status of fish populations in Fort Devens aquatic systems has not been fully defined (ABB-ES, 1992c).

Rare and endangered species at Fort Devens include the federally listed (endangered) bald eagle and peregrine falcon (both occasional transients); the state-listed (endangered) upland sandpiper, ovoid spike rush, and Houghton's flatsedge; the state-listed (threatened) Blanding's turtle, cattail sedge, pied-billed grebe, and northern harrier; and the state-listed (special concern) blue-spotted

salamander, grasshopper sparrow, spotted turtle, wood turtle, water shrew, blackpoll warbler, American bittern, Cooper's hawk, sharp-shinned hawk, and Mystic Valley amphipod. Also state-listed as rare or endangered are three Lepidoptera (butterfly and moth) species identified at Fort Devens.

The Massachusetts Natural Heritage Program (MWHP) has developed Watch Lists of unprotected species that are uncommon or rare in Massachusetts. From the Watch Lists, 14 plant species, two amphibian species, and 15 bird species have been observed at Fort Devens.

Additional detail concerning the ecology of Fort Devens can be found in Section 7.0.

3.2.4 Physiography

Fort Devens is in a transitional area between the coastal lowland and central upland regions of Massachusetts. All of the landforms are products of glacial erosion and deposition on a crystalline bedrock terrain. Glacial erosion was superimposed on ancient bedrock landforms that were developed by the erosional action of preglacial streams. Generally, what were bedrock hills and ridges before the onset of Pleistocene glaciation were only moderately modified by glacial action, and they remain bedrock hills and ridges today. Similarly, preglacial bedrock valleys are still bedrock valleys. In post-glacial time, streams have locally modified the surficial glacial landforms but generally have not affected bedrock.

The predominant physiographic (and hydrologic) feature in the Fort Devens area is the Nashua River. It forms the eastern installation boundary on the South Post, where its valley varies from a relatively narrow channel (at Still River Gate), to an extensive floodplain with a meandering river course and numerous cutoff meanders (at Oxbow National Wildlife Sanctuary). The Nashua River forms the western boundary of much of the Main Post, and there its valley is deep and comparatively steep-sided with extensive bedrock outcroppings on the eastern bank. The river flows through the North Post in a well-defined channel within a broad forested floodplain.

Terrain at Fort Devens falls generally into three types. The least common is bedrock terrain, where rocks that have been resistant to both glacial and fluvial

erosion remain as topographic highs, sometimes thinly veneered by glacial deposits. Shepley's Hill on the Main Post is the most prominent example.

A similar but more common terrain at Fort Devens consists of materials (tills) deposited directly by glaciers as they advanced through the area or as the ice masses wasted (melted). These landforms often conform to the shape of the underlying bedrock surface. They range from areas of comparatively low topographic relief (such as near Lake George Street on the Main Post) to elongated hills (drumlins) whose orientations reflect the direction of glacier movement (such as Whittemore Hill on the South Post).

The third type of terrain was formed by sediment accumulations in glacial-meltwater streams and lakes (glaciofluvial and glaciolacustrine deposits). This is the most common terrain at Fort Devens, comprising most of the North and South Posts and much of the Main Post. Its form bears little or no relationship to the shape of the underlying bedrock surface. Landforms include extensive flat uplands such as the hills on which MAAF and the wastewater infiltration beds are located on the North Post. Those are large remnants of what was once a continuous surface that was later incised and divided by downcutting of the Nashua River. Another prominent glacial meltwater feature is the area around Cranberry Pond and H-Range on the South Post. This is classic kame-and-kettle topography formed by sand and gravel deposition against and over large isolated ice blocks, followed by melting of the ice and collapse of the sediments. The consistent elevations of the tops of these ice-contact deposits are an indication of the glacial-lake stage with which they are associated. Mirror Lake and Little Mirror Lake on the Main Post occupy another conspicuous kettle.

3.2.5 Soils

Fort Devens lies within Worcester County and Middlesex County in Massachusetts (see Figure 3-1). The soils of Worcester County have been mapped by the Soil Conservation Service (SCS) of the U.S. Department of Agriculture (USDA) (USDA, 1985). Mapping of the soils of Middlesex County has not been completed. However, an interim report (USDA, 1991), field sheet #19 (USDA, 1989), and an unpublished general soil map (USDA, undated) are available.

Soil mapping units ("soil series") that occur together in intricate characteristic patterns in given geographic areas are grouped into soil "associations." Soils in

the Worcester County portions of Fort Devens consist generally of three associations. Three associations also have been mapped in the Middlesex County portions of Fort Devens. Although the mapped associations are not entirely the same on both sides of the county line, the differences reflect differences in definition and the interim status of Middlesex County mapping. The general distributions of the soil associations are shown in Figure 3-2, and descriptions of the soil series in those associations are provided below.

WORCESTER COUNTY (USDA, 1985)

Winooski-Limerick-Saco Association:

Winooski Series. Very deep; moderately well drained; slopes 0 to 3 percent; occurs on floodplains; forms in silty alluvium.

Limerick Series. Very deep; poorly drained; slopes 0 to 3 percent; occurs on floodplains; forms in silty alluvium.

Saco Series. Very deep; very poorly drained; slopes 0 to 3 percent; occurs on floodplains; derived mainly from schist and gneiss.

Hinckley-Merrimac-Windsor Association:

Hinckley Series. Very deep; excessively drained; slopes 0 to 35 percent; occurs on stream terraces, eskers, kames, and outwash plains.

Merrimac Series. Very deep; excessively drained; slopes 0 to 25 percent; occurs on stream terraces, eskers, kames, and outwash plains.

Windsor Series. Very deep; moderately well drained; slopes 0 to 3 percent; occurs on floodplains.

Paxton-Woodbridge-Canton Association:

Paxton Series. Very deep; well drained; slopes 3 to 35 percent; occurs on glacial till uplands; formed in friable till overlying firm till.

Woodbridge Series. Very deep; moderately well drained; slopes 0 to 15 percent; occurs on glacial till uplands; formed in firm till.

Canton Series. Very deep; well drained; slopes 3 to 35 percent; occurs on glaciated uplands; formed in friable till derived mainly from gneiss and schist.

MIDDLESEX COUNTY (USDA, 1991)

Hinckley-Freetown-Windsor Association (This is a continuation of the Hinckley-Merrimac-Windsor Association mapped in Worcester County):

Hinckley Series. Deep; excessively drained; nearly level to very steep; occurs on glacial outwash terraces, kames, and eskers; formed in gravelly and cobbley coarse-textured glacial outwash.

Freetown Series. Deep; very poorly drained; nearly level, organic; occurs in depressions and on flat areas of uplands and glacial outwash plains.

Windsor Series. Deep; excessively drained; nearly level to very steep; occurs on glacial outwash plains, terraces, deltas, and escarpments; formed in sandy glacial outwash.

Quonset-Carver Association:

Quonset Series. Deep; excessively drained; nearly level to very steep; occurs on glacial outwash plains, terraces, eskers, and kames; formed in water-sorted sands derived principally from dark phyllite, shale, or slate.

Carver Series. Deep; excessively drained; nearly level to steep; occurs on glacial outwash plains, terraces, and deltas; formed in coarse, sandy, water-sorted material.

Winooski-Limerick-Saco Association (This is a continuation of the same association mapped along the Nashua River floodplain in Worcester County).

3.2.6 Surficial Geology

Fort Devens lies in three topographic quadrangles: Ayer, Clinton, and Shirley. The surficial geology of Fort Devens has been mapped only in the Ayer quadrangle (Jahns, 1953) and Clinton quadrangle (Koteff, 1966); the Shirley quadrangle is unmapped.

Unconsolidated surficial deposits of glacial and postglacial origin comprise nearly all of the exposed geologic materials at Fort Devens. The glacial units consist of till, deltaic deposits of glacial Lake Nashua, and deposits of glacial meltwater streams.

The till ranges from unstratified gravel to silt, and it is characteristically bouldery. Jahns (1953) and Koteff (1966) recognize a deeper unit of dense, subglacial till, and an upper, looser material that is probably a slightly younger till of englacial or superglacial origin. Till is exposed in ground-moraine areas of the Main Post (such as in the area of Lake George Street) and on the South Post at and south of Whittemore Hill. It also underlies some of the water-laid deposits (Jahns, 1953). Till averages approximately 10 feet in thickness but reaches 60 feet in drumlin areas (Koteff, 1966).

Most of the surficial glacial units in the Nashua Valley are associated with deposition in glacial Lake Nashua, which formed against the terminus of the Wisconsinan ice sheet as it retreated northward along the valley. Successively lower outlets were uncovered by the retreating glacier, and the lake level was correspondingly lowered. Koteff (1966) and Jahns (1953) recognize six lake levels (stages) in the Fort Devens area, distinguished generally by the elevations and distribution of their associated deposits. The stages are, in order of development: Clinton Stage; Pin Hill Stage; Old Mill Stage; Harvard Stage; Ayer Stage; and Groton Stage.

The glacial lake deposits consist chiefly of sand and gravelly sand. Coarser materials are found in topset beds of deltas built out into the lakes and in glacial streambeds graded to the lakes. Delta foreset beds are typically composed of medium to fine sand, silt, and clay. Lake-bottom deposits, which consist of fine sand, silt, and clay, are mostly covered by delta deposits and are seldom observed in glacial Lake Nashua deposits. One of the few known exposures of glacial lake-bottom sediments in the region is on the South Post near A- and C-Ranges.

There, a section of more than 14 feet of laminated clay was mined for brick-making in the early part of this century (Alden, 1925, pp. 70-71). The general physical characteristics of glacial lake deposits are the same regardless of the particular lake stage in which the deposits accumulated (Koteff, 1966; Jahns, 1953). Although glaciofluvial and glaciolacustrine sediments are typically well stratified, correlations between borings are difficult because of laterally abrupt changes characteristic of these generally high-energy depositional environments.

Postglacial deposits consist mostly of river-terrace sands and gravels; fine alluvial sands and silts beneath modern floodplains; and muck, peat, silt, and sand in swampy areas.

Jahns (1953) also observed a widespread veneer of windblown sand and ventifacts above the glacial materials (and probably derived from them in the brief interval between lake drainage and the establishment of vegetative cover).

3.2.7 Bedrock Geology

Fort Devens is underlain by low-grade metasedimentary rocks, gneisses, and granites. The rocks range in age from Late Ordovician to Early Devonian (approximately 450 million to 370 million years old). The installation is situated approximately 2 miles west of the Clinton-Newbury-Bloody Bluff fault zone, which developed when the ancestral European continental plate collided with and underthrust the ancestral North American plate. The continents reseparated in the Mesozoic to form the modern Atlantic Ocean. Fort Devens is located on the very eastern edge of the ancestral North American continental plate. A piece of the ancestral European continent (areas now east of the Bloody Bluff fault) broke off and remained attached to North America.

Preliminary bedrock maps (at scale 2,000 feet/inch) are available for the Clinton quadrangle (Peck, 1975 and 1976) and Shirley quadrangle (Russell and Allmendinger, 1975; Robinson, 1978). Bedrock information for the Ayer quadrangle is from the Massachusetts state bedrock map (at a regional scale of 4 miles/inch) (Zen, 1983) and in associated references (Robinson and Goldsmith, 1991; Wones and Goldsmith, 1991). Among these sources, there is some disagreement about unit names and stratigraphic sequence; however, there is general agreement about the distribution of rock types.

In contrast to the high metamorphic grade and highly sheared rocks of the Clinton-Newbury zone, the rocks in the Fort Devens area are low grade metamorphics (generally below the biotite isograd) and typically exhibit less brittle deformation. Major faults have been mapped, however, including the Wekepeke fault exposed west of Fort Devens (in an outcrop 0.25 mile west of the old Howard Johnson rest stop on Route 2).

Figure 3-3 is a generalized summary of the bedrock geology of Fort Devens. It is compiled from Peck (1975), Robinson (1978), Russell and Allmendinger (1975), and Zen (1983), and it adopts the nomenclature of Zen (1983). Because of limited bedrock exposures, the locations of mapped contacts are considered approximate, and the mapped faults are inferred. Rock units strike generally northward to northeastward but vary locally. The bedrock units underlying Fort Devens are as follows:

DSw **WORCESTER FORMATION** (Lower Devonian and Silurian) Carbonaceous slate and phyllite, with minor metagraywacke to the west (Zen, 1983; Peck, 1975). Bedding is typically obscure because of a lack of compositional differences. It is relatively resistant to erosion and forms locally prominent outcrops. The abandoned Shaker slate quarry on the South Post is in rocks of the Worcester Formation. The unit corresponds to the "DSgs" and "DSs" units of Peck (1975) and the "e3" unit of Russell and Allmendinger (1975).

So **OAKDALE FORMATION** (Silurian) Metasiltstone and phyllite. It is fine-grained and consists of quartz and minor feldspar and ankerite, and it is commonly deformed by kink banding (Zen, 1983; Peck, 1975; Russell and Allmendinger, 1975). In outcrop it has alternating layers of brown siltstone and greenish phyllite. The Oakdale Formation crops out most visibly on Route 2 just east of the Jackson Gate exit. It corresponds to the "DSsp" unit of Peck (1975), the "e2" unit of Russell and Allmendinger (1975), and "ms" unit of Robinson (1978).

Sb **BERWICK FORMATION** (Silurian) Thin- to thick-bedded metamorphosed calcareous metasiltstone, biotitic metasiltstone, and fine-grained metasandstone, interbedded with quartz-muscovite-garnet schist and feldspathic quartzite (Zen, 1983; Robinson and Goldsmith, 1991). In

areas northwest of Fort Devens, cataclastic zones have been observed (Robinson, 1978).

Dcgr **CHELMSFORD GRANITE** (Lower Devonian) Light-colored and gneissic, even and medium grained, quartz-microcline-plagioclase-muscovite-biotite, pervasive ductile deformation visible in elongate quartz grains aligned parallel to mica. It intrudes the Berwick Formation and Ayer granite (Wones and Goldsmith, 1991).

AYER GRANITE

Sacgr **Clinton facies** (Lower Silurian) Coarse-grained, porphyritic, foliated biotite granite with a nonporphyritic border phase; it intrudes the Oakdale and Berwick Formations and possibly the Devens-Long Pond Facies (Zen, 1983; Wones and Goldsmith, 1991).

SOad **Devens-Long Pond facies** (Upper Ordovician and Lower Silurian) Gneissic, equigranular to porphyoblastic biotite granite and granodiorite. Its contact relationship with the Clinton facies is unknown (Wones and Goldsmith, 1991). Observations of mapped exposures of this unit on Fort Devens indicate that it may not be intrusive.

Bedrock is typically unweathered to only slightly weathered at Fort Devens. Glaciers stripped away virtually all of the preglacially weathered materials, and there has been insufficient time for chemical weathering of rocks in the comparatively brief geologic interval since glacial retreat.

3.2.8 Regional Hydrogeology

Fort Devens is in the Nashua River drainage basin, and the Nashua River is the eventual discharge locus for all surface water and groundwater flow at the installation.

The water of the Nashua River has been assigned to Class B under Commonwealth of Massachusetts regulations. Class B surface water is "designated for the uses of protection and propagation of fish, other aquatic life and wildlife, and for primary and secondary contact recreation" (314 CMR 4.03).

The principal tributaries of the north-flowing Nashua River at Fort Devens are Nonacoicus Brook and Walker Brook on the North Post; Cold Spring Brook (which is a tributary of Nonacoicus Brook) on the Main Post; and Spectacle Brook and Ponakin Brook (tributaries of the North Nashua River), Slate Rock Brook, and New Cranberry Pond Brook on the South Post.

There are two ponds on Fort Devens' South Post that are called Cranberry Pond. For the purpose of this report, the isolated kettle pond located east of H-Range is referred to as Cranberry Pond, and the pond impounded in the 1970s, 0.5-mile west of the Still River gate, is referred to as New Cranberry Pond.

Glacial meltwater deposits constitute the primary aquifer at Fort Devens. In aquifer tests performed as part of the Groups 2 and 7 Site Investigation (ABB-ES, 1993b), measured hydraulic conductivities in meltwater deposits were comparatively high - typically 10^{-3} to 10^{-2} centimeters per second (cm/sec). In till and in clayey lake-bottom sediments, measured hydraulic conductivities were lower and ranged generally from 10^{-6} to 10^{-4} cm/sec. Groundwater also occurs in the underlying bedrock; however, flow is limited because the rocks have very little primary porosity and water moves primarily in fractures and dissolution voids.

Groundwater in the surficial aquifer at Fort Devens has been assigned to Class I under Commonwealth of Massachusetts regulations. Class I consists of groundwaters that are "found in the saturated zone of unconsolidated deposits or consolidated rock and bedrock and are designated as a source of potable water supply" (314 CMR 6.03).

The transmissivity of an aquifer is the product of its hydraulic conductivity and saturated thickness, and as such it is a good measure of groundwater availability. Figure 3-4 shows aquifer transmissivities at Fort Devens, based on the regional work of Brackley and Hansen (1977). Transmissivities in the meltwater deposits range from 10 square feet per day (ft^2/day) to more than 4,000 ft^2/day. Aquifer transmissivities between 10 and 1,350 ft^2/day correspond to potential well yields generally between 10 and 100 gpm; transmissivities from 1,350 to 4,000 ft^2/day typically yield from 100 to 300 gpm; and where transmissivities exceed 4,000 ft^2/day, well yields greater than 300 gpm can be expected. (Most domestic wells in the area are drilled 100 to 200 feet into bedrock and yield less than 10 gpm. Higher yields are associated with deeper bedrock wells.)

In Figure 3-4, the zones of highest transmissivity are found in areas of thick glacial meltwater deposits on the North and Main Posts, and these encompass the Sheboken, Patton, and McPherson production wells and the largely inactive Grove Pond wellfield. The zones of lowest transmissivity are associated with exposed till and bedrock and are located on the Main Post surrounding Shepley's Hill and between Jackson Gate and the parade ground, and on the South Post at Whittemore Hill and isolated areas to the north and west.

A regional study of water resources in the Nashua River basin was reported by Brackley and Hansen (1977). A digital model of groundwater flow at Fort Devens is available in a draft final report by Engineering Technologies Associates, Inc. (1992).

According to Engineering Technologies Associates, Inc. (1992), in the absence of pumping or other disturbances, groundwater recharge occurs in upland areas (e.g., the high ground on the Main Post between Queenstown, Givry, and Lake George Streets, and on the South Post the area around Whittemore Hill). The groundwater flows generally from the topographic highs to topographic lows. It discharges in wetlands, ponds, streams, and directly into the Nashua River. Groundwater discharge maintains the dry-weather flow of the rivers and streams.

3.3 Shepley's Hill Landfill

Shepley's Hill landfill occupies approximately 84 acres in the northeast corner of the Main Post at Fort Devens (Figure 3-5). The landfill has been capped according to an approved closure plan and final closure activities are scheduled for 1993. Wastes potentially disposed of in the landfill include incinerator ash (from burning household debris), glass, spent shell casings, and asbestos. Reportedly, flammable fluids were also disposed of in the southern portion of the landfill.

Shepley's Hill Landfill is bordered to the east by Plow Shop Pond and the Boston and Maine Railroad, to the north by Nonacoicus Brook Wetland, to the west by Shepley's Hill (a large gneiss outcrop), and to the south by the DRMO area and the Main Post.

3.3.1 Geology

The following subsections describe the surficial and bedrock geology of the Shepley's Hill Landfill area.

3.3.1.1 Surficial Geology. Shepley's Hill Landfill lies within the Ayer topographic quadrangle. The surficial geology of the Ayer quadrangle was mapped in 1941 by Jahns (Jahns, 1953). The soils in and around Shepley's Hill Landfill are predominantly unconsolidated, poorly graded fine to medium sands with gravel, cobbles and a silt content ranging between 1 and 15 percent. Soils in the landfill area are part of the Hinckley-Merrimack-Windsor Association and are associated with deposition in glacial Lake Nashua, which formed against the terminus of the Wisconsinan ice sheet. Depositional features include a kame terrace, a glacially deposited hill of stratified sands and gravels, with an elevation of 250 feet ASL located in the northeast corner of the landfill, and prominent cross beds in an exposed channel fill feature 100 feet west of SHL-7. The uppermost portion of the unconsolidated deposits consists of fine aeolian deposited sand. Palustrine sediments, such as peat, are probably located below fill material in the central and north-central sections of the landfill between Shepley's Hill and the kame plateau. Maps indicate that these areas were swamps prior to landfilling operations and may have been the result of a small kettle lake. Dense silt, 1 to 10 feet thick, was encountered at the overburden bedrock interface in borings SHL-1, SHL-4, SHL-16, SHL-25 (E&E, 1993), and SHM-93-01A. This silt may represent a till, and contained gravel to cobble size pieces of slightly weathered gneiss and phyllite. The unconsolidated overburden reaches a maximum observed thickness of 115 feet at both the northern and southern portions of the landfill. Across the central portion of the landfill the overburden thickness is estimated to range from 25 to 50 feet dependent on landforms. The overburden over the entire landfill has the general trend of thinning to the west where it abuts the Shepley's Hill outcrop.

3.3.1.2 Bedrock Geology. The surficial soils at Shepley's Hill Landfill are underlain by low-grade phyllitic metasiltstones and biotite rich gneiss. The metasiltstone is calcareous with secondary quartz and sulfides along bedding planes and fractures. Extensive folding, banding, and foliation is also evident. The metasiltstones are only slightly weathered with small (0.1 to 0.5 inch) solution cavities. The bedrock core obtained from SHM-93-10C was moderately fractured in the uppermost 10 feet and became increasingly competent with depth. The

fractures occurred chiefly along bedding planes although some fractures were nearly perpendicular in bedding. The foliation was observed to be dipping at 45 to 50 degrees but was nearly vertical in areas. The following boreholes encountered metasiltstone: SHL-10, SHL-24 (E&E, 1993), SHM-93-10C, and SHM-93-22C. The bedrock core from SHM-93-22C indicates that bedrock at this location is a low-grade gneiss. The metasiltstones below Shepley's Hill Landfill belong to the Silurian Berwick Formation.

The gneiss, which appears from outcrops to be nonintrusive, is characterized by its high biotite content, gneissic foliation, and elongated feldspathic porphyroblasts. The following boreholes encountered varying metamorphic grades of gneiss: SHL-1, SHL-2, SHL-3, SHL-4, SHL-5, SHL-8, SHL-11, SHL-14, SHL-20, and SHL-22 (E&E, 1993). The gneiss, which is associated with the Devens-Long Pond facies of the Ayer Granite (Upper Ordovician and Lower Silurian) is only slightly weathered. The gneiss directly underlies unconsolidated materials beneath most of the landfill outcropping to the west at Shepley's Hill and to the southwest near the DRMO yard and adjacent to the Petroleum Oil and Lubricants (POL) yard. The 20 feet of gneiss core obtained from SHM-93-22C contained only three natural fractures, all within the uppermost 10 feet. Secondary quartz and quartzite occur throughout the rock along healed fractures. Both open and healed fractures were observed to be dipping at approximately 50 degrees. The Berwick Formation metasiltstone occurs only in the southeast corner of the landfill.

Figure 3-6 presents an interpretation of bedrock topography in the Shepley's Hill Landfill Area. It appears that a bedrock ridge extends from SHL-1 eastward below Plow Shop Pond. The evidence supporting the existence of the ridge includes the bedrock elevation of 215.7 feet ASL, at monitoring well SHM-93-01A. This is 5 feet higher than the bedrock elevation at SHM-93-10C which is 250 feet to the northeast. This change in elevation would be consistent with the presence of a ridge aligned east-northeastward from Shepley's Hill to below Plow Shop Road. The results of the seismic survey indicated a bedrock high between SHL-3 and SHL-11 with bedrock elevations rising above 200 feet ASL. The seismic survey data may be explained by a local, closed bedrock high not just the presence of a ridge. Exposed bedrock topography also supports the existence of a ridge; the gneiss that comprises Shepley's Hill juts out to the east near SHL-1 along the line of the axis of the inferred ridge. Furthermore, the prelandfill ground surface contours in Figure 3-6, and the presence of a generally

coincident topographic high with a superimposed shallow swampy depression suggests a shallow bedrock substrate.

The bedrock topography along the southern boundary of the landfill is characterized by a series of hills and valleys that appear to trend roughly north-south.

Bedrock along the northern end of the landfill is characterized by a deep valley increasing in depth toward Nonacoicus Brook.

3.3.2 Plow Shop Pond Sediments

Plow Shop Pond is underlain with a thick layer of black, highly organic sediment consisting of partially decomposed roots, leaves, and wood. Sediment thickness reaches a maximum of at least 8 feet in the center of the pond (> 8 feet at SHD-92-08X and SHD-92-21X) and thins toward the eastern and western shores of the pond (2.5 feet at SHD-92-03X, 3 feet at SHD-92-01X, and 4.5 feet at SHD-92-18X along the western shore, and 4 feet at SHD-92-12X and 1.5 feet at SHD-92-19X along the eastern shore near the culvert). Refer to Figure 2-1 for sampling locations and Table 2-1 for sediment thicknesses.

3.3.3 Nonacoicus Brook Wetland Soils

Soil samples were collected at four locations within the wetland west of Nonacoicus Brook. Surficial samples at SHD-92-29X, SHD-92-30X, SHD-92-31X, and SHD-92-32X range from silty sand to sandy silt. Samples collected from the same locations at depths from 1 to 2 feet had much higher sand and gravel contents and ranged from silty sand to gravely sand.

Sampling locations are shown in Figure 2-2. Results of grain-size distribution analyses are provided in Table 2-2.

3.3.4 Groundwater Hydrology

Groundwater present in the overburden represents the primary aquifer in the Shepley's Hill Landfill area. Groundwater also occurs in the underlying bedrock; however, there is little or no primary effective porosity. Groundwater flow can occur along bedrock fractures and solution cavities.

Groundwater in the area flows primarily from the west-southwest to the east and north (Figure 3-7). Discharge areas for groundwater around the landfill included Plow Shop Pond and the wetland north of West Main Street in Ayer. The presence of the dam in the northwest corner of Plow Shop Pond has raised the pond surface elevation in this area above the groundwater elevation, thereby locally reversing the gradient and causing water to discharge from Plow Shop Pond. The point where the gradient reverses varies seasonally depending on pond and groundwater elevation. The transition generally occurs midway between SHL-20 and SHL-21. Groundwater to the north of this point flows toward the wetland, while groundwater to the south discharges to Plow Shop Pond.

Measured groundwater levels indicate a groundwater divide exists to the southwest of the landfill below the DRMO yard. The divide occurs along a northwest-southeast trending line between monitoring well 32M-92-07X and Shepley's Hill. Groundwater to the northeast of this divide flows eastward and northeastward under the southern portion of the landfill, while groundwater to the southwest of the divide flows to the southwest away from the landfill. The overburden aquifer appears to be recharged at least in part, by groundwater discharging from the bedrock along the western border of the landfill. The relationship between the bedrock aquifer and the overburden aquifer in the center of the cap is unknown; however, it is possible that the bedrock aquifer may also discharge to the overburden in this area. Vertical hydraulic gradients between the bedrock aquifer and the overburden show an upward gradient of 0.05 feet per foot (ft/ft) between SHM-93-10C and SHL-10 and 0.026 ft/ft between SHL-24 and SHM-93-24A. An upward gradient of 0.004 ft/ft exists between the deep overburden well SHM-93-18B and the water table well SHL-18. A downward gradient of 0.13 ft/ft appears to occur in the northern section of the landfill between the bedrock well SHM-93-22C and the water table well SHL-22. No measurable vertical gradient occurs between SHL-8S and SHL-8D in the northeast corner of the landfill.

Upward vertical gradients are observed along the southeastern and eastern perimeters of Shepley's Hill Landfill as would be expected as groundwater discharges to Plow Shop Pond. A downward gradient and lack of vertical gradient are observed in the northern and northeastern portions of the landfill. This is consistent with Plow Shop Pond discharging to the overburden aquifer due to the presence of the dam. The groundwater ultimately discharges to the wetland north of West Main Street and to the Nashua River.

The landfill cap covers approximately 84 acres (Biang, 1992). The cap has reduced or eliminated infiltration from precipitation, and lowered the water table beneath it. The likely result of lowering the water table has been to impart a more northerly component of flow in the southern section of the landfill as is observed in the bend of the 225 foot contour near the southern portion of the landfill in Figure 3-7. Water levels in monitoring wells SHL-12 and SHL-17 are nearly identical even though the wells are approximately 280 feet apart. ABB-ES interprets this to mean the 225 foot contour must be roughly parallel to a line between the two wells.

Permeability testing of the newly installed Shepley's Hill Landfill monitoring wells produced hydraulic conductivity estimates ranging from $2x10^{-2}$ cm/sec to $5x10^{-4}$ cm/sec for the unconfined overburden aquifer and $3x10^{-5}$ cm/sec to $5x10^{-7}$ cm/sec for the bedrock aquifer. These values were determined by the Hvorslev analyses, values for the both Hvorslev and Bouwer and Rice analyses are provided in Table 2-5 and Appendix C.

3.3.5 Surface Water Hydrology

Shepley's Hill Landfill is bordered to the northeast by Plow Shop Pond, a shallow, 30 acre pond outside the installation boundary. The water level in Plow Shop Pond is maintained by two dams, one in the northwest corner on Nonacoicus Brook and one on the north side of the pond near Moores Lumber Yard. Flow into Plow Shop Pond is through a culvert from Grove Pond to the east. The railroad causeway separating Plow Shop Pond and Grove Pond is thought to have been constructed in the late 1800s. Before construction of the causeway and dams, Plow Shop Pond and Grove Pond were most likely a continuous swampy area fed by a number of small streams. Nonacoicus Brook flows approximately 1 mile to the northwest from Plow Shop Pond before it discharges to the Nashua River. A wetland borders the brook and is a local groundwater discharge area north of West Main Street in Ayer. The area surrounding Nonacoicus Brook to the south of West Main Street is referred to as Nonacoicus Brook Wetland, but the downward vertical gradient of 0.13 ft/ft between SHM-93-22C and SHL-22 and the lack of a measurable vertical gradient between SHL-85 and SHL-8D suggests that this is not a local discharge area. In addition, the area bordering Nonacoicus Brook to the north of West Main Street has surface water all year while the area to the south of West Main Street has surface water only during flood events.

3.4 COLD SPRING BROOK LANDFILL

Cold Spring Brook Landfill is an abandoned landfill located in the southeast part of the Main Post at Fort Devens (Figure 3-8). Landfilling was reported to have begun 45 years ago. The area now occupied by the landfill was a swamp at the headwaters of Cold Spring Brook. After the start of landfilling along Patton Road, the culvert at the outlet of Cold Spring Brook was raised to create a pond that now abuts part of the landfill. Based upon aerial photographs, this occurred before 1970.

3.4.1 Geology

The following subsections describe the surficial and bedrock geology of the Cold Spring Brook Landfill area.

3.4.1.1 Surficial Geology. Cold Spring Brook Landfill lies within the Ayer topographic quadrangle. The surficial geology of the Cold Spring Brook Landfill area is predominantly unconsolidated, silty sand to poorly graded medium to fine sand and organic palustrine sediments. The sands are associated with deposition in glacial Lake Nashua, which formed against the terminus of the Wisconsinan ice sheet. A topographically high kame plain, a prominent glacial depositional feature, is located south of Patton Road. Before construction of the landfill, a swampy area stretched from Cold Spring Brook to the base of the kame. The swamp, which may originally have been a kettle pond, extended from approximately 75 feet east of CSB-2 to 50 feet east of CSB-6. USGS maps from 1935 show Patton Road originally bending to the south around the swampy area near what is now CSB-3. The remnants of this section of road are still visible. The present stretch of Patton Road in this area is built on fill.

Extensive peat deposits exist to the west of CSB-5 between the northern margin of the landfill and Cold Spring Brook. At CSM-93-01A, the remnants of this peat layer were first encountered at 19 feet. Rubble and construction debris have deformed and mixed with the peat layer forming a matrix of well-graded sand and gravel within the peat. A second and presumably older peat layer was encountered at 34.5 feet bgs in CSM-93-01A and extended to approximately 40 feet bgs, below which there are stratified sands.

3.4.2.2 Bedrock Geology. Bedrock was encountered at 129.6 feet bgs at CSM-93-02B. Bedrock coring and classification were not performed at CSM-93-02B or any of the other new or existing monitoring wells at Cold Spring Brook Landfill. However, bedrock in the area has been mapped as the Devens-Long Pond facies of Ayer Granite (Zen, 1983).

3.4.2 Cold Spring Brook Pond Sediment

Sediment cores obtained from the 10 vibratory core sampling locations showed a sediment blanket of highly organic, partially decomposed, viscous sediments (peat) overlying fine to coarse sands and silty sands. The sediment thickness varies from 0.5 feet at CSB-92-10X to 4.7 feet at CSB-92-09X. As would be expected sediment layers were thickest in low energy, low flow environments and thinner in areas of higher water flow. Sampling locations are shown in Figure 2-8. Results of grain-size distribution and soil classification are presented in Appendix D and Table 2-6.

3.4.3 Magazine Area Soils

Soil samples were collected at three locations near the southeast corner of the Magazine Area. Surficial samples at MAD-92-01X and MAD-92-03X were silty sands with a high content of decomposed organics. MAD-92-02X was gravelly sand with 12 percent organics. Sampling locations are shown in Figure 2-8. Results of grain-size distribution analyses are provided in Appendix D and Table 2-7.

3.4.4 Groundwater Hydrology

The unconsolidated overburden represents the primary aquifer in the Cold Spring Brook Landfill area. The Patton Well, located west-southwest of the Cold Spring Brook Landfill, is one of three groundwater production wells servicing the Main Post and is screened from 55.5 to 60.5 feet bgs and from 70.5 to 85.5 feet bgs. Groundwater flow in the area appears to mimic topography, flowing from the north and south and discharging into Cold Spring Brook Pond (Figure 3-9). Groundwater flow in the vicinity of CSB-2 and westward appears to be influenced by the pumping of the Patton Road water supply well.

Water level data from monitoring wells CSB-4 and CSB-5 were not used to evaluate piezometric surface. Both wells are screened in peat, which has the general effect of locally mounding the water table. In addition, the integrity of monitoring well CSB-5 is in question. The well was repaired in 1993 after being non-functioning for several years. It appears that during repair the screen may have become partially blocked with bentonite.

Permeability testing of the three newly installed Cold Spring Brook Landfill monitoring wells produced estimates of hydraulic conductivity for the overburden aquifer. Hydraulic conductivity estimates ranged from $1x10^{-3}$ cm/sec to $8x10^{-4}$ cm/sec. These values were determined by the Hvorslev Analyses. Values for both the Hvorslev and Bouwer and Rice Analyses are provided in Table 2-10 and Appendix C.

3.4.5 Surface Water Hydrology

Cold Spring Brook Pond is the major surface water feature adjacent to the landfill. Cold Spring Brook Pond drains to Cold Spring Brook to the east via a culvert beneath Patton Road. The western corner of the pond is fed seasonally by surface water draining from the Magazine Area. Based on interpreted groundwater hydrology (Subsection 3.4.4), the pond is also a groundwater discharge area. At times of low water levels, the western arm of Cold Spring Brook Pond, between CSB-1 and CSB-2, becomes isolated from the main pond as the connecting channel becomes discontinuous. In late summer and fall, standing water disappears from this area of the pond.

Engineering Technologies Associates, Inc. will be performing a detailed hydrogeologic investigation of the Cold Spring Brook Landfill Area.

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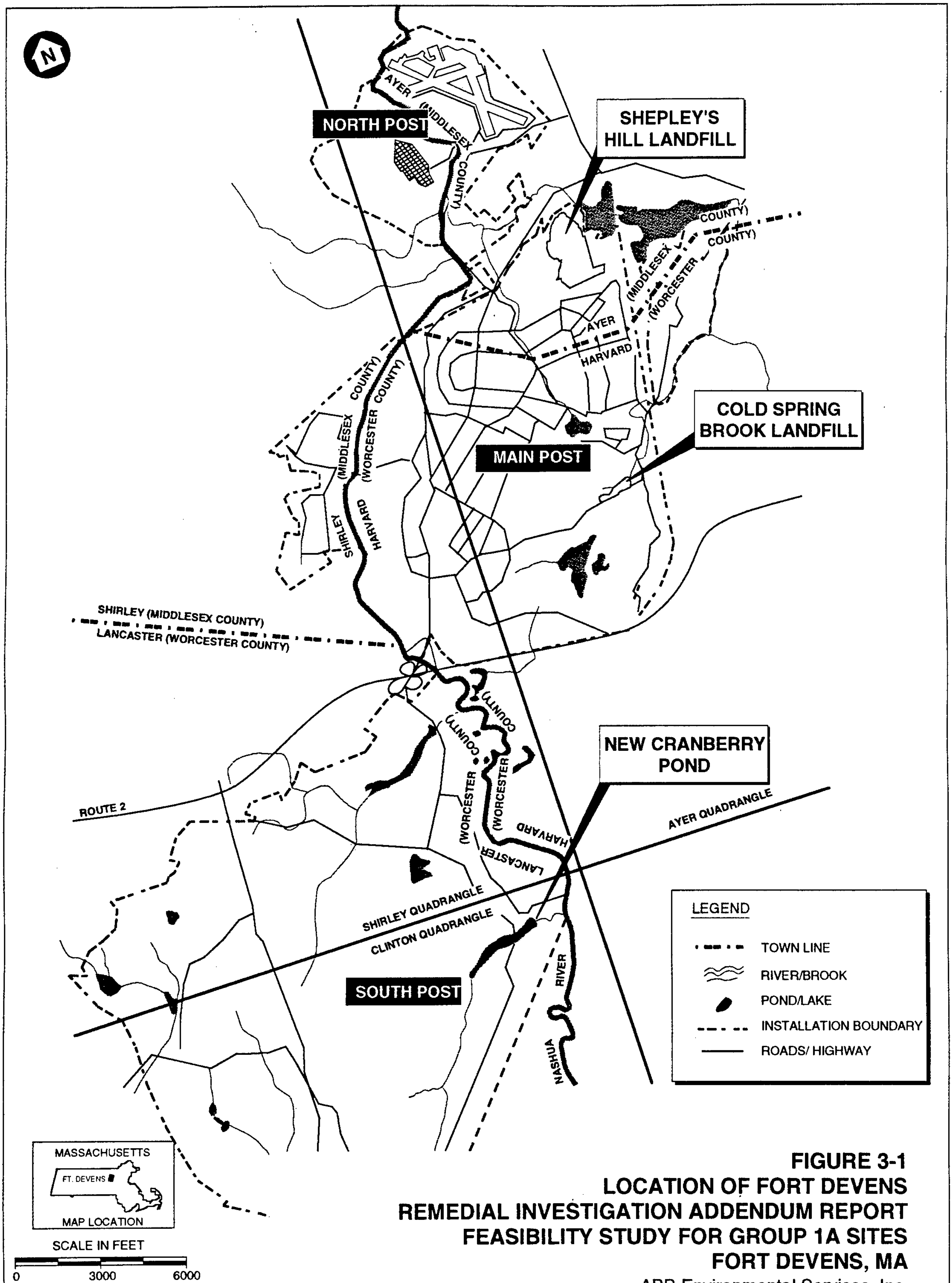

FIGURE 3-1
LOCATION OF FORT DEVENS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9307026D 1

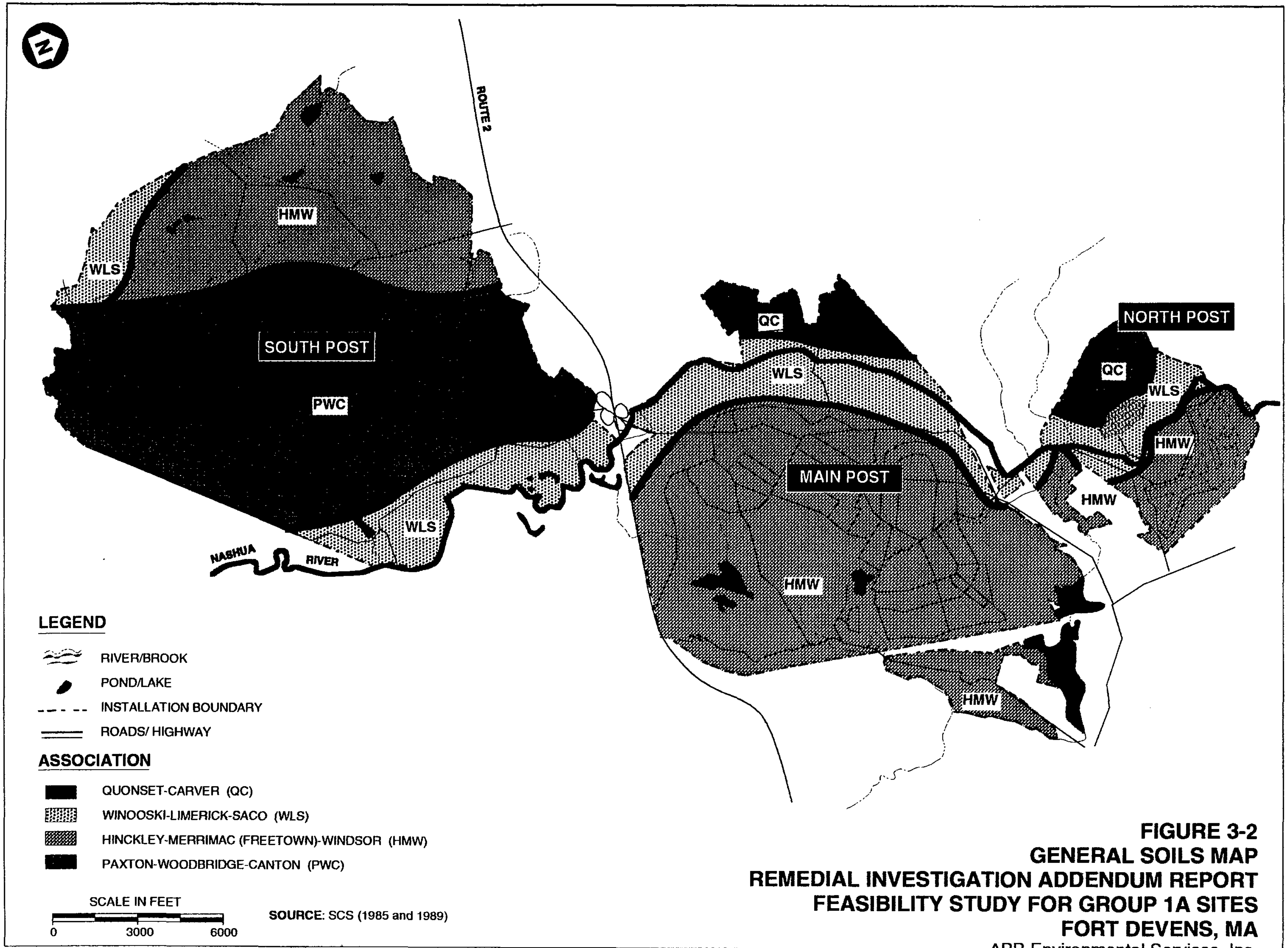

FIGURE 3-2
GENERAL SOILS MAP
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

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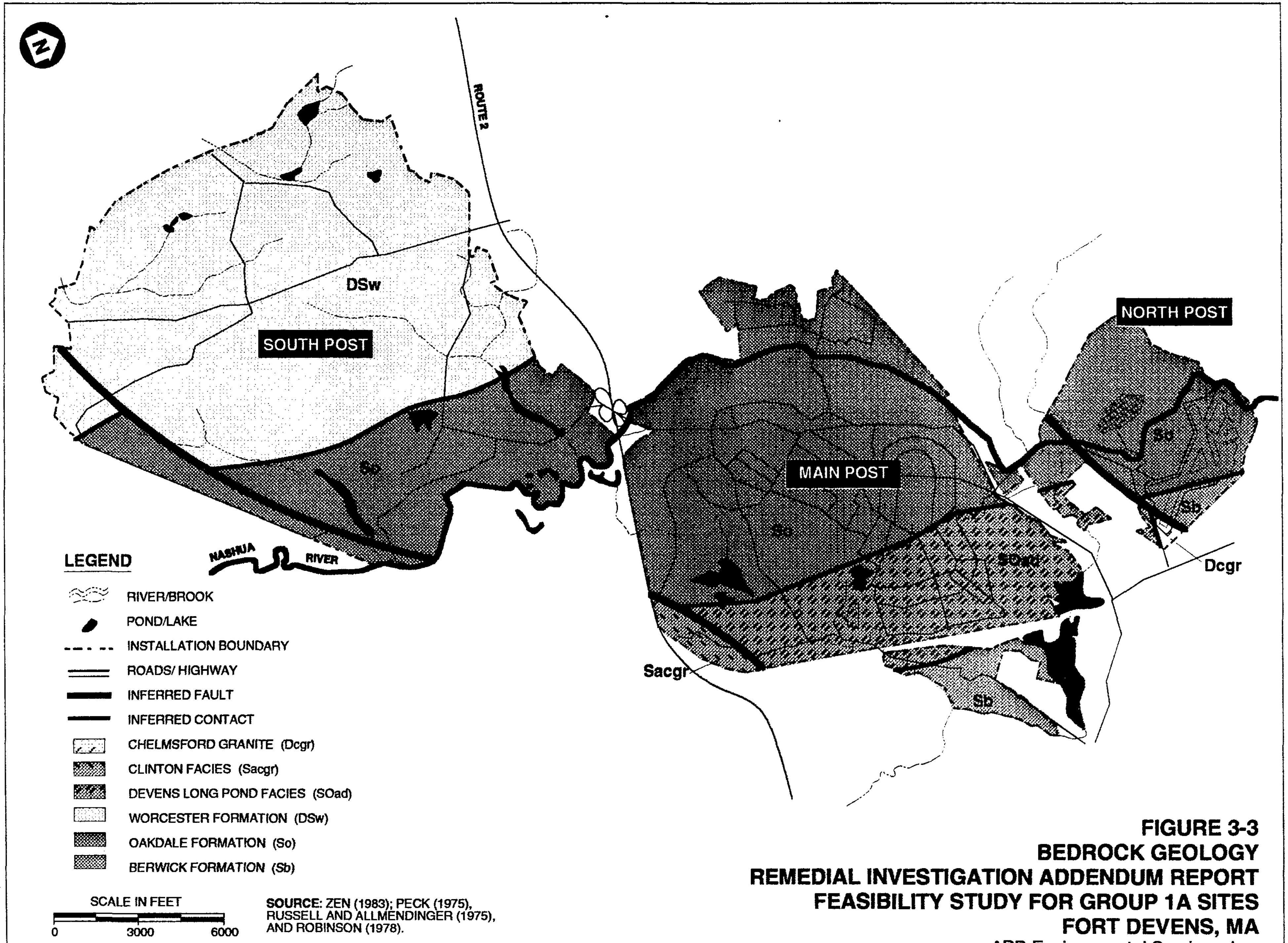

FIGURE 3-3
BEDROCK GEOLOGY
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

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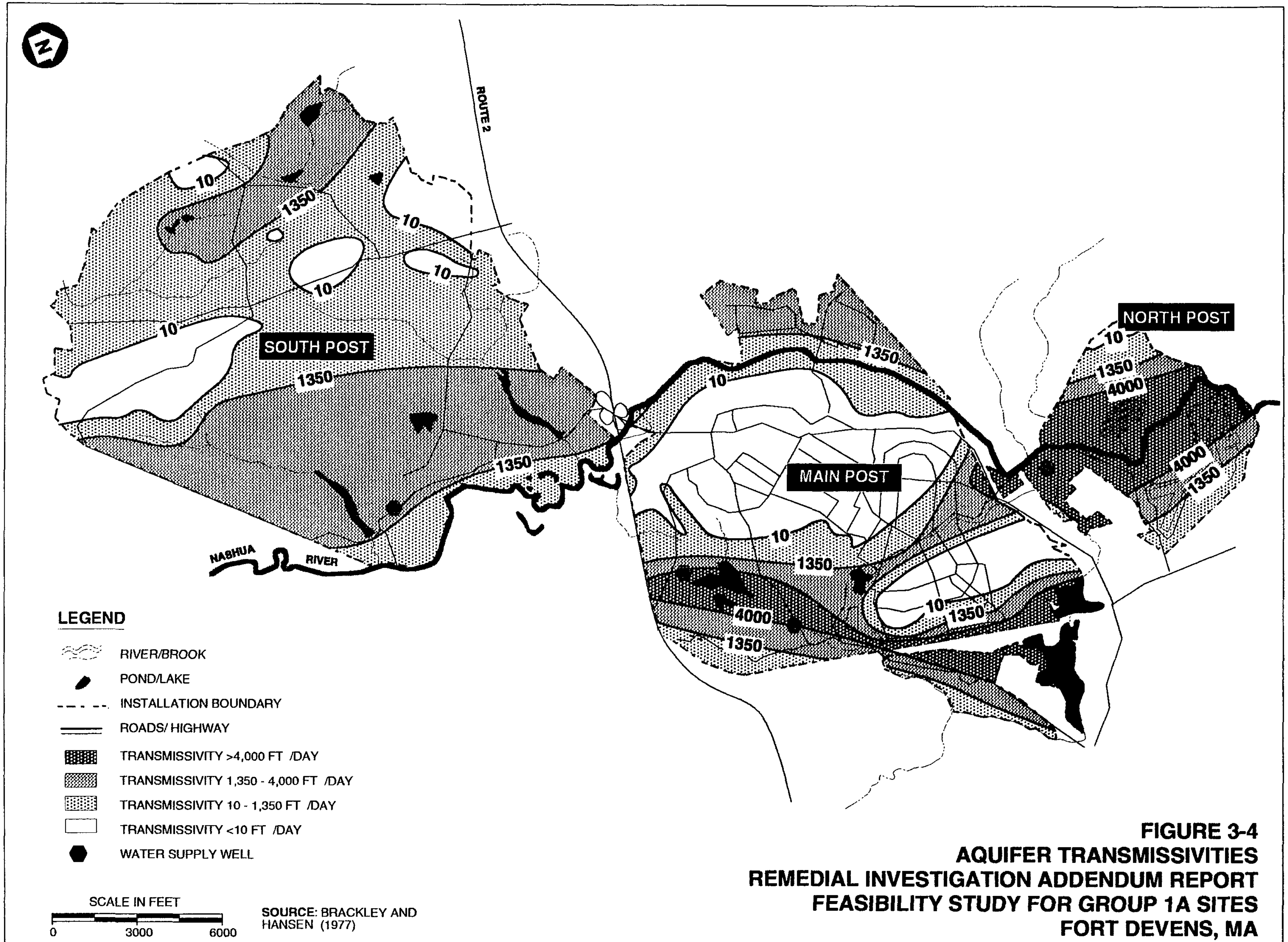

FIGURE 3-4
AQUIFER TRANSMISSIVITIES
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

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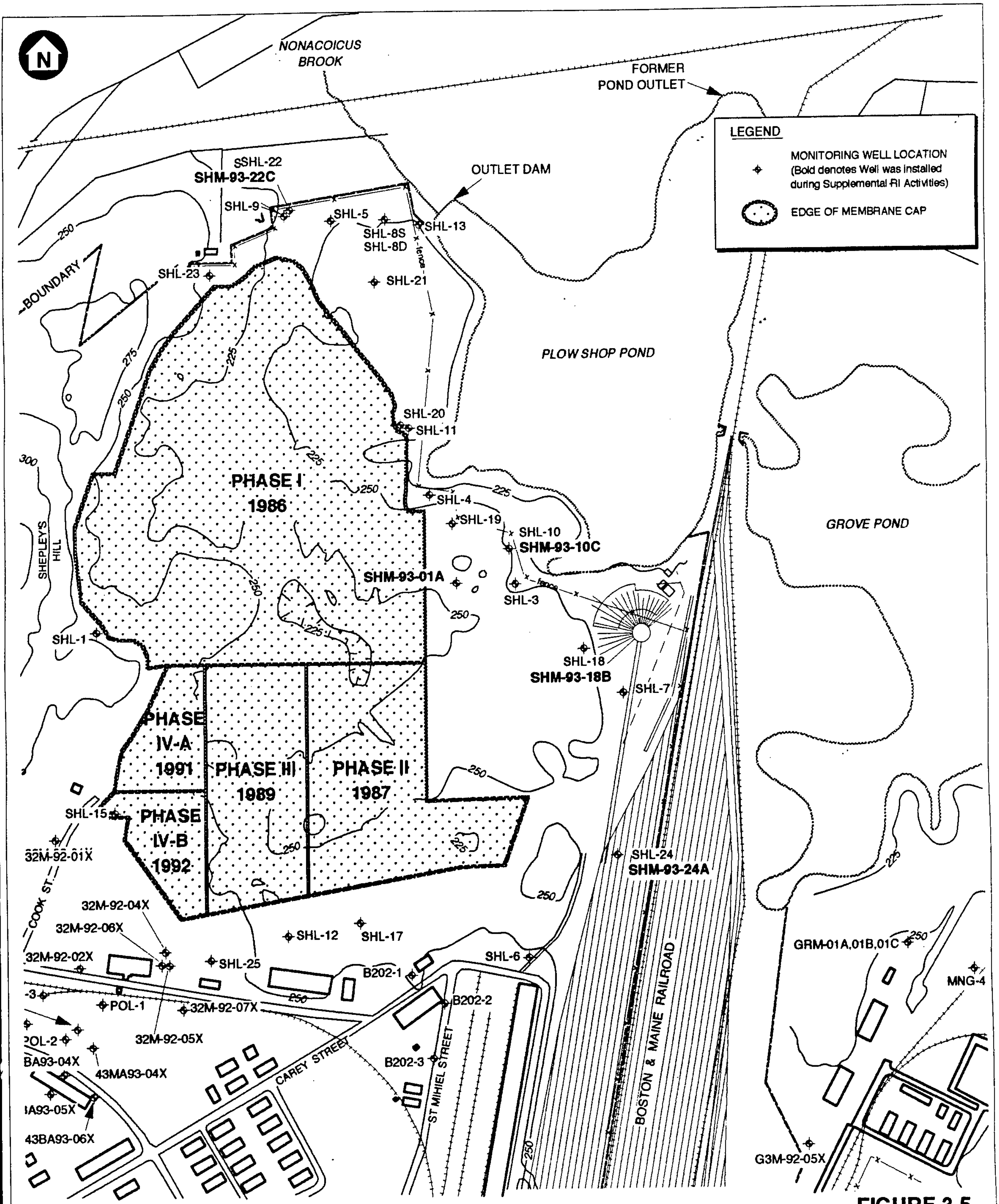


NOTE: Topographic Contours Beneath Landfill Cap Represent Surficial Topography Prior To Landfilling Operations

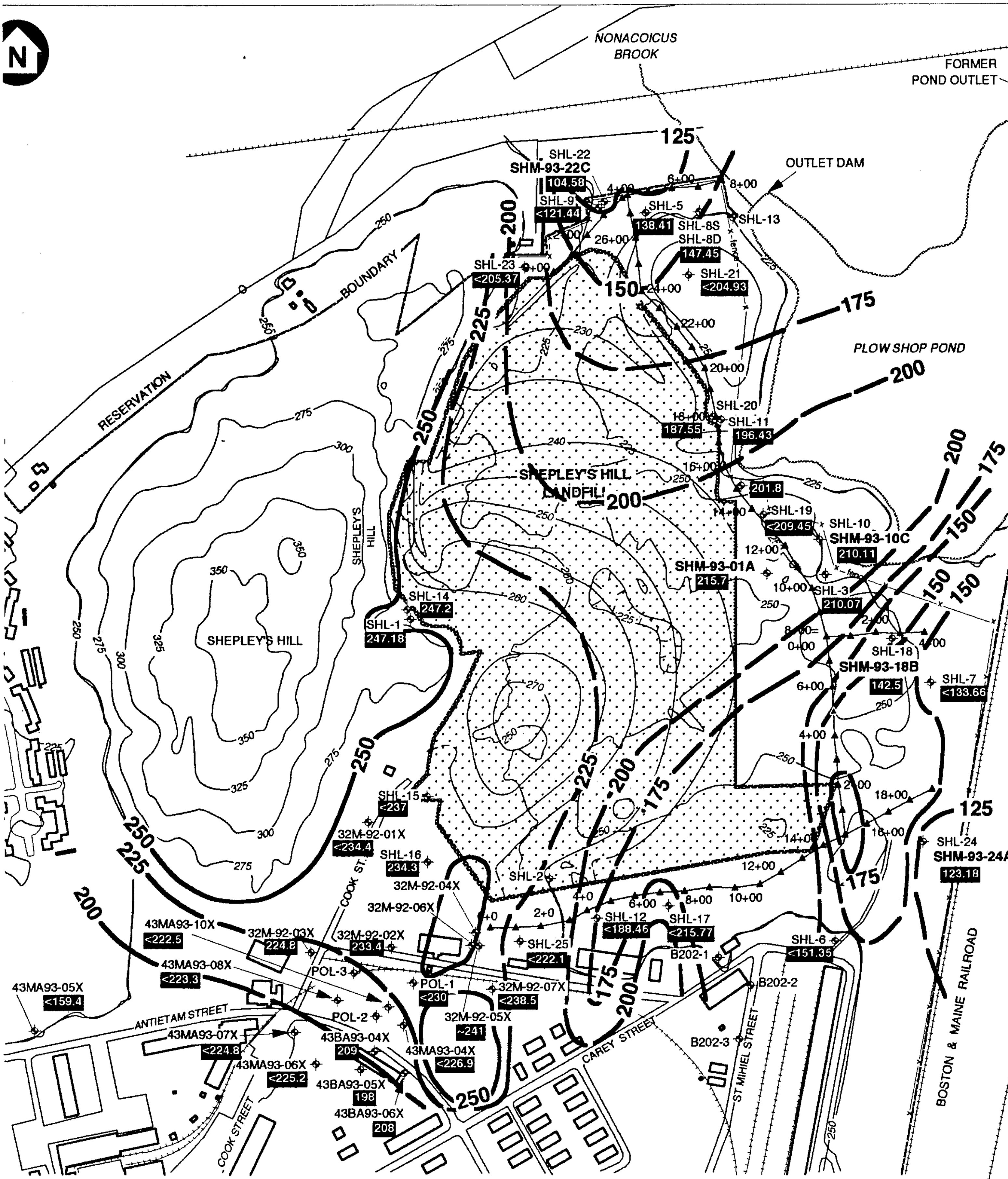
SCALE IN FEET

0 500 1000

FIGURE 3-5
SHEPLEY'S HILL LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9303022D 12SB6TE



NOTE: Topographic Contours Beneath Landfill Cap Represent Surficial Topography Prior To Landfilling Operations

SCALE IN FEET

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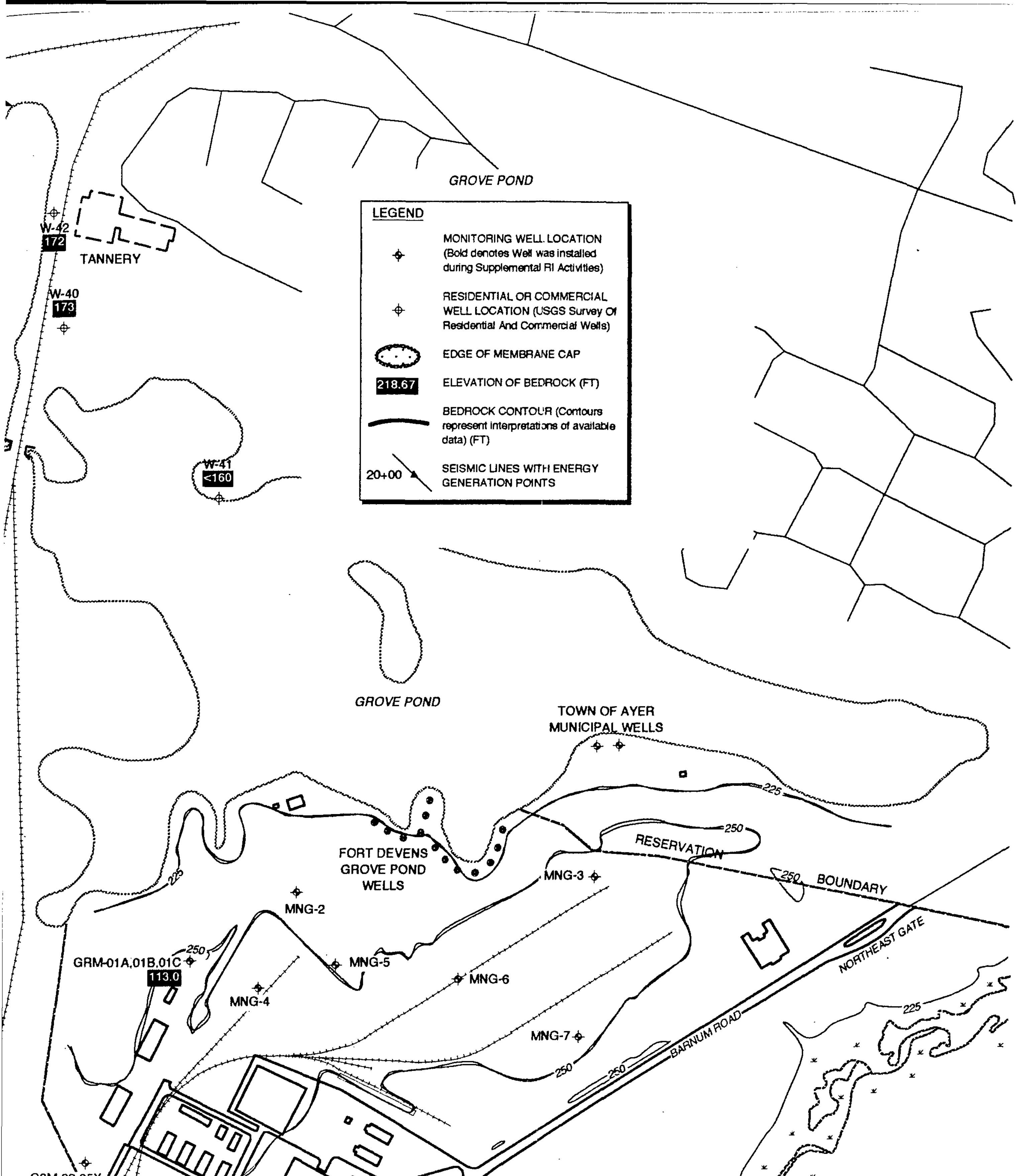

FIGURE 3-6
BEDROCK TOPOGRAPHY
SHEPLEY'S HILL LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FT. DEVENS, MA

ABB Environmental Services, Inc.

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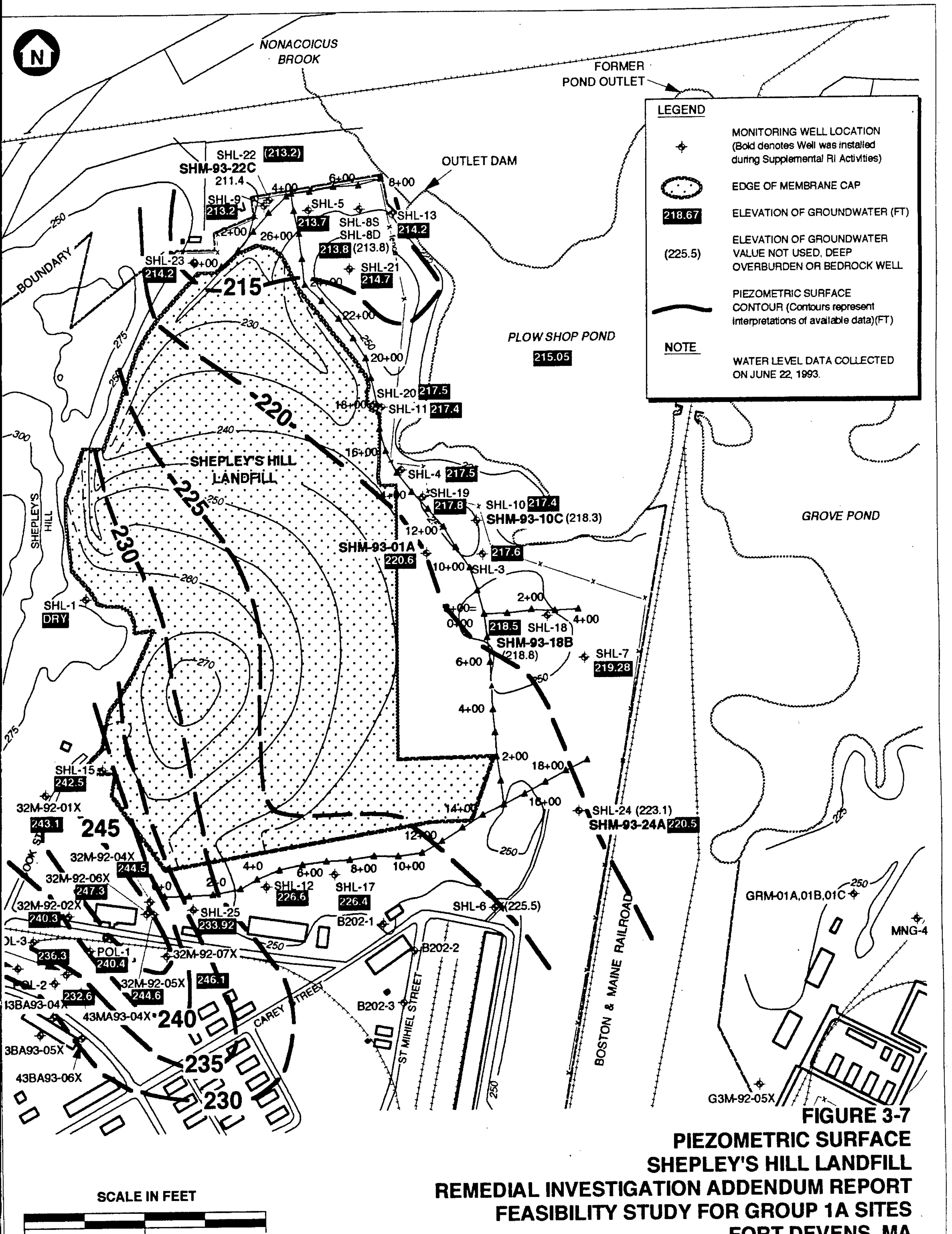

FIGURE 3-7
PIEZOMETRIC SURFACE
SHEPLEY'S HILL LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

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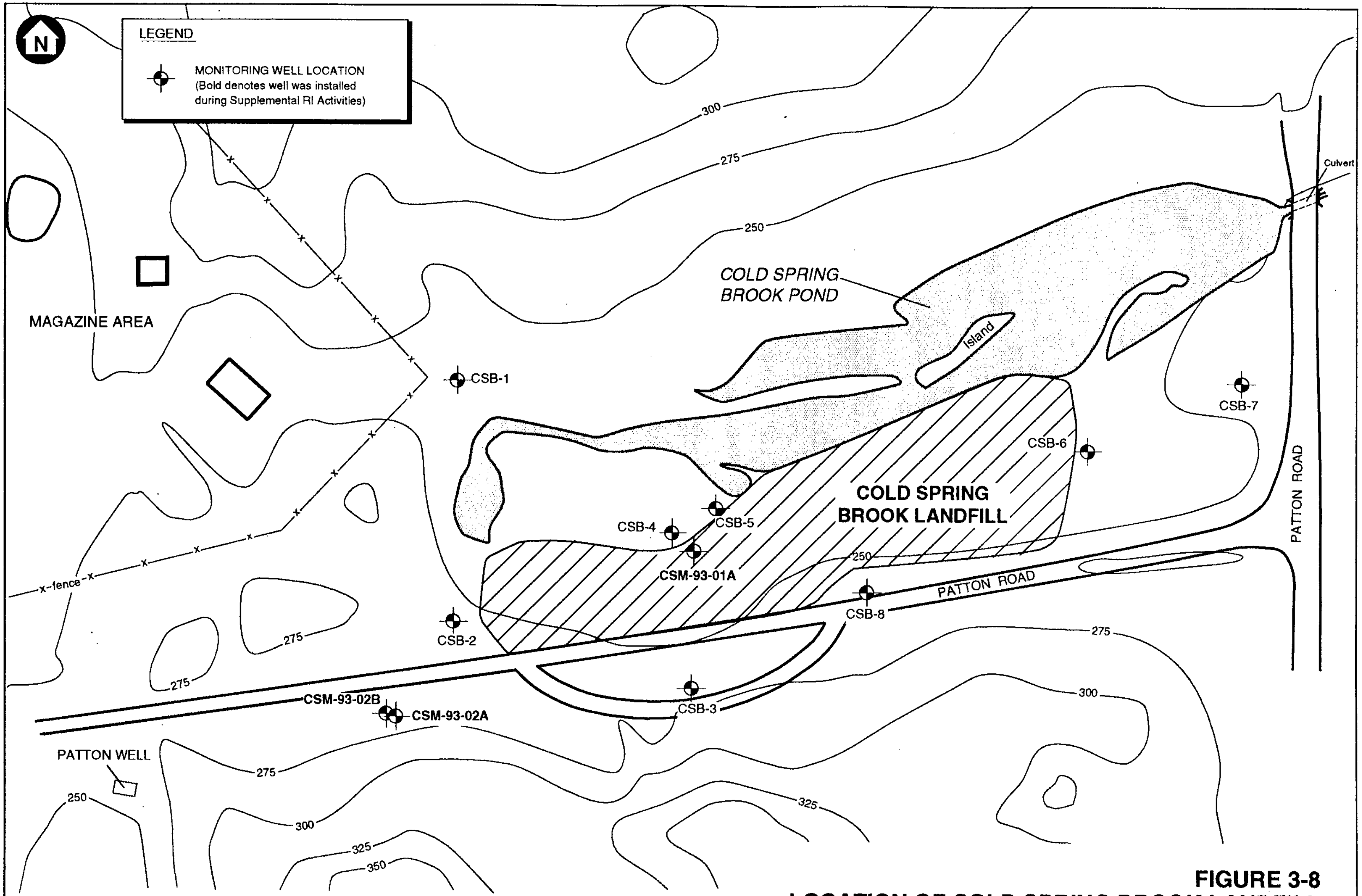

FIGURE 3-8
LOCATION OF COLD SPRING BROOK LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

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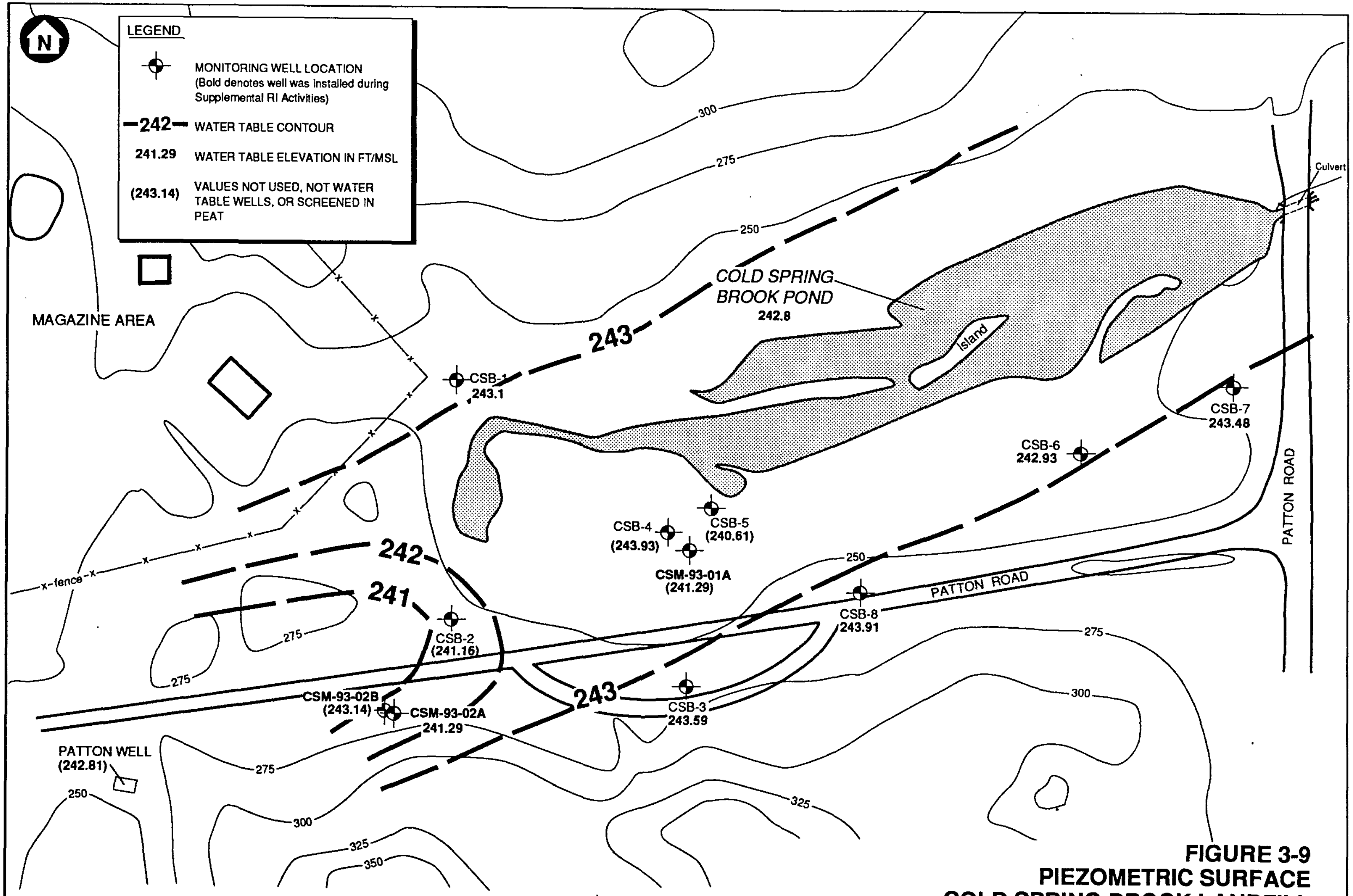

SCALE IN FEET

0 200 400

NOTE

MEASUREMENTS COLLECTED ON MAY 17, 1993.

FIGURE 3-9
PIEZOMETRIC SURFACE
COLD SPRING BROOK LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

9305033D 2 4 78

ABB Environmental Services, Inc.

4.0 NATURE AND EXTENT OF CONTAMINATION

This section evaluates the nature and extent of contamination in groundwater, surface water, soil, and sediments at Shepley's Hill and Cold Spring Brook landfills, as well as at several adjacent or related areas. The results of landfill gas monitoring at Shepley's Hill Landfill are also discussed. The data for evaluation result primarily from analysis of samples collected by ABB-ES as part of the data gap activities for Group 1A sites. Data collected by E&E during the RI are discussed briefly in certain instances to enable a more complete evaluation of contamination. A complete reassessment of RI data is not provided. The purpose of evaluation is to identify chemicals considered to be contaminants. The identification of contaminants of potential concern (COPCs) is done in the risk assessments contained in Sections 6.0 and 7.0.

The contamination assessment is based on the following general rules:

- Detected organic compounds are considered contaminants unless specifically excluded.

- Inorganic chemicals in soil and groundwater are considered contaminants if detected concentrations exceed Fort Devens 68th percentile upperbound "background" values and if they are not otherwise excluded.

- Inorganic chemicals in sediment are considered contaminants if detected concentrations exceed USEPA Region V values for arsenic, barium, chromium, copper, iron, lead, manganese, nickel, and zinc (USEPA, 1977). Ontario Ministry of the Environment criteria are considered for cadmium and mercury (Persaud, 1992).

- Because background data are not available for surface water, data for Grove Pond surface water are compared to Ambient Water Quality Criteria (AWQC) to enable a qualitative evaluation of water quality. An exceedance of AWQC is not used to classify a chemical as a contaminant.

- Chemicals were not considered contaminants if they were detected at low concentrations and/or low frequency (i.e., less than 5 percent of the samples for data sets (by media) containing 20 or more samples).

- Chemicals were not considered contaminants if they were present at less than 5-times observed blank concentrations.

Concentrations of inorganic analytes detected in soil and groundwater samples were compared to 68th percentile upperbound limits calculated for Fort Devens. Calculations were based on analytical data results gathered from soil and groundwater samples collected throughout the Fort Devens installation, selected as representative of background (non-contaminated) conditions. Though most of the calculations include assumptions about both the distribution of chemical concentrations and on the selection of representative samples that are not statistically rigorous, the results are considered representative of actual background concentrations at Fort Devens.

For soil, chemical data gathered from 20 soil samples collected by E&E as part of their Group 1A and 1B investigation activities were used. The samples were collected from the major soil associations throughout Fort Devens specifically to establish background concentrations of inorganic analytes in soil. After these data were reviewed, apparent statistical outliers were eliminated from the data sets, and the 68th percentile upperbound (the mean value plus one standard deviation) was calculated. Though environmental data are rarely truly "normally distributed," it was assumed that the resulting 68th percentile concentrations were representative of installation-wide background concentrations. Outlier values were identified in the data sets using both graphical observation and relative changes to recalculated 68th percentile values (i.e., outliers were removed from the data sets only if a significant decrease in the recalculated 68th percentile was observed).

The calculations were performed on 19 of the 23 PAL inorganic analytes (no data were available for antimony, cobalt, selenium, and thallium). In special cases, where an analyte was not detected in a given sample, ABB-ES used a value of one-half the detection limit of the analyte in the statistical analysis. For analytes that were not detected in more than one-half of the soil samples, the detection limit for that analyte was selected as the background concentration. Table 4-1

presents calculated 68th percentile upperbound concentrations for inorganics in soil. Data ranges, mean values, and details of the calculations are provided in Appendix I.

For groundwater, ABB-ES selected 10 representative unfiltered groundwater samples collected from the Round 1 groundwater sampling events for SA Groups 2, 7 and 3, 5, 6 for the purpose of calculating background inorganic analyte concentrations. Representative groundwater samples were selected from upgradient monitoring wells exhibiting low TSS and/or low aluminum concentrations. Knowing that elevated TSS concentrations often artificially elevate inorganic analyte concentrations, ABB-ES selected samples that exhibited TSS concentrations on the same order of magnitude as the South Post Water Supply Well (i.e., representative of typical TSS concentrations in potable groundwater). Because a close correlation between TSS concentrations and aluminum concentrations was observed in all the groundwater samples analyzed, the aluminum concentration was used as an alternate selection criterion in the absence of TSS data. The concentration values detected in the 10 samples were calculated using the same assumptions on outliers and detection limits applied to the soils background concentration calculations. Table 4-1 presents calculated 68th percentile upperbound concentrations for inorganics in groundwater. Data ranges, mean values, and details of the calculations are provided in Appendix I. Table 4-2 presents the sediment evaluation criteria.

4.1 SHEPLEY'S HILL LANDFILL

This subsection assesses the presence and distribution of contamination in groundwater at Shepley's Hill Landfill and in Plow Shop Pond sediments. The discussion of inorganics in groundwater focuses first on unfiltered sample analytical results followed by a discussion of factors that may modify the reader's interpretation.

4.1.1 Shepley's Hill Landfill Groundwater

Review of hydrologic and analytical data enables identification of three distinct monitoring well groupings at Shepley's Hill Landfill: a southern cross-gradient group, a downgradient group, and a northern cross-gradient group. The southern cross-gradient group contains seven monitoring wells located south and east of the

landfill. These wells, listed from west to east, are as follows: SHL-25, SHL-12, SHL-17, SHL-6, SHL-24, SHM-93-24A, and SHL-7 (see Figure 3-7).

The downgradient group contains 14 monitoring wells located along the northern and eastern edge of the landfill: SHL-9, SHL-22, SHM-93-22C, SHL-5, SHL-11, SHL-20, SHL-4, SHL-19, SHL-10, SHM-93-10C, SHM-93-01A, SHL-3, SHL-18, and SHM-93-18B.

The northern cross-gradient group contains monitoring wells SHL-8S, SHL-8D, SHL-13, and SHL-21. These wells are located northeast of the landfill and are interpreted to be hydrologically cross-gradient of the landfill and downgradient of Plow Shop Pond.

Three monitoring wells, SHL-1, SHL-15, and SHL-23, do not fit into any of the three groupings. Well SHL-1 is an upgradient well located at the western edge of the landfill. It was dry during supplemental RI groundwater sampling and no sample was collected from it. SHL-15 is located at the southwest corner of the landfill. It was installed as an upgradient/background monitoring well during the RI, but was found to be contaminated. Well SHL-23 is a hydrologically upgradient monitoring well located at the northwest corner of the landfill.

Groundwater samples were collected from 22 existing and five newly installed monitoring wells during Round 1 groundwater sampling and from the five new monitoring wells during Round 2 and analyzed for PAL VOCs, pesticides and PCBs, explosives, inorganics, TOC, TSS, TDS, alkalinity, and hardness. Samples from 15 of the Round 1 monitoring wells and 3 of the Round 2 (new) monitoring wells were field filtered and analyzed for dissolved PAL inorganics. Field filtering and dissolved metals analysis were performed to enable assessment of the contribution of suspended solids to total metal concentrations. The effect of field filtering at Shepley's Hill Landfill is discussed at the end of this subsection. Table 4-3 summarizes Round 1 groundwater analytical data.

Organics. Review of the Round 1 data indicates that a total of ten VOCs were detected at low concentrations in 12 of the wells. Maximum detected concentrations and the wells in which they were found are listed below.

ANALYTE	FREQUENCY	MAXIMUM CONCENTRATION (μg/L)	MAX. WELL
Benzene	3/27	1.7	SHL-11
Chloroethane	1/27	5.5	SHL-20
Chloroform	5/27	0.87	SHL-10
Dichlorobenzenes	1/27	11	SHL-20
1,1-Dichloroethane	4/27	4.4	SHM-93-10C
1,2-Dichloroethane	4/27	9.9	SHM-93-10C
1,2-Dichloroethylenes	6/27	7	SHM-93-10C
1,2-Dichloropropane	1/27	0.52	SHL-22
Trichloroethylene	1/27	0.57	SHL-25
Trichlorofluoromethane	1/27	2.1	SHL-15

Note: μg/L = micrograms per Liter.

The maximum observed VOC concentrations were 11 μg/L for dichlorobenzene in overburden monitoring well SHL-20, and 9.9 μg/L for 1,2-dichloroethane in bedrock monitoring well SHM-93-10C. This concentration of 1,2-dichloroethane exceeds the MCL of 5 μg/L. The greatest number of compounds and the highest concentrations were detected in monitoring wells SHM-93-10C, SHL-19, SHL-11, and SHL-20 along the eastern edge of the landfill and in well SHL-22 at the north end of the landfill. Lower concentrations were reported in bedrock well SHM-93-22C, located close to SHL-22. All these wells are hydrologically downgradient of the landfill. Wells SHL-25, hydrologically cross-gradient, and SHL-18, located downgradient but near the interpreted cross- gradient boundary, each had only one reported VOC. The trichloroethylene reported at 0.57μg/L in monitoring well SHL-25 may have originated at the former site of underground storage tank (UST) 13, located within AOC 32, about 150 feet to the west, before the tank was removed.

Organic compounds were reported in samples from the two bedrock monitoring wells (SHM-93-10C, SHM-93-22C) installed during the supplemental field program. These two bedrock wells are screened approximately 10 to 20 feet below the bedrock surface. Well SHM-93-10C is installed in phyllite, a metamorphosed siltstone, and well SHM-93-22C is installed in gneiss, a metamorphic rock. Both rock types have extremely low primary porosity, but exhibit some secondary porosity at Shepley's Hill Landfill in the form of fractures and solution cavities (phyllite only). Neither is interpreted as likely to transmit appreciable volumes of groundwater over long distances. The presence of VOCs in samples from these two bedrock wells is attributed to induced recharge during well development and purging from contaminated groundwater in overlying overburden. The deep overburden monitoring well SHL-22 had higher concentrations of 1,1-dichloroethane and 1,2-dichloroethylene than well SHM-93-22C located adjacent to it. It is also possible that groundwater in well SHM-93-10C was contaminated by induced recharge from a contaminated silty-sand veneer overlying the bedrock. Groundwater within the silty matrix may exchange poorly with groundwater in the sands above the silty matrix, and development and purging of well SHM-93-10C may have lead to the detection of VOCs in the well. Well SHL-19 located about 200 feet cross-gradient is screened within a silty layer and shows contamination similar to well SHM-93-10C.

Chloroform was reported at concentrations up to 0.87 μg/L in five Round 1 samples and was pervasive in rinsate blanks at concentrations up to 33 μg/L. Its presence in samples is considered an artifact of decontamination procedures; it is not considered a groundwater contaminant (see Appendix H). These VOC data are generally comparable to data obtained during E&E's RI activities in terms of compounds detected, concentrations, and locations where found. Notable exceptions are that vinyl chloride, which was reported in one well during the August 1991 RI sampling, and methylene chloride, a suspected laboratory contaminant during the RI, were not found during the supplemental RI. The VOCs tetrachloroethylene and 1,1,2,2-tetrachloroethane were found once in two rounds of RI sampling. They were not detected in supplemental RI samples.

No pesticides or PCBs were reported in the groundwater samples. This supports a reinterpretation of groundwater data presented in the final RI report. Although pesticides were reported at low concentrations in several RI samples, no well had a hit in both RI sampling rounds. In addition, Subsection 5.1.6.3 of the final RI report states that several pesticides including heptachlor, endrin, alpha- and

beta-BHC, DDT, and endosulfan sulfate were detected in method blank samples and that low concentrations of those compounds should be considered due to laboratory contamination. Analytical difficulties were noted for PCBs. Subsection 5.2.6.3 of the final RI report also indicates difficulties with the pesticides analysis. These considerations and the supplemental RI data support the conclusion that the landfill is not a source of pesticides or PCBs in groundwater.

The explosive nitroglycerine was reported in one monitoring well, the water table well SHM-93-24A, at 80.8 μg/L. This well is considered cross-gradient of the landfill and the source of the nitroglycerine is not known. The landfill is not considered a source of nitroglycerine. The explosives 1,3,5-trinitrobenzene, 1,3-dinitrobenzene and tetryl were reported inconsistently and at low concentrations in RI samples, they were not detected in the supplemental RI samples. SVOCs were not identified as groundwater contaminants in E&E's RI report or targeted as analytes during the supplemental field program. They are not considered groundwater contaminants at Shepley's Hill Landfill.

The data obtained during Round 2 sampling and analysis generally confirm the Round 1 results (Table 4-4). The sample from well SHM-93-10C contained 1,1-dichloroethane and 1,2-dichloroethane at essentially the same concentrations as in Round 1, and the sample from well SHM-93-22C contained 1,2-dichloroethane at essentially the same concentration as the Round 1 sample. Organics were not detected in the Round 2 samples from wells SHM-93-18B and SHM-93-24A, similar to Round 1. Variances from Round 1 included the low concentration detection of 1,2-dichloroethane (0.84 μg/L) in the sample from SHM-93-01A and toluene (0.56 μg/L) in SHM-93-22C. Acetone was also reported in samples from wells SHM-93-01A and SHM-93-10C at 14 and 15 μg/L, respectively.

Inorganics. Unfiltered Round 1 samples from the southern cross-gradient wells were characterized by inorganic concentrations below or slightly exceeding Fort Devens background concentrations (see Figure 3-7). In monitoring well SHL-17, only the concentration of calcium exceeded background (18,800 μg/L versus 14,700 μg/L), and in well SHL-25 only the concentration of potassium exceeded background (2,670 μg/L versus 2,370 μg/L). Wells SHL-6, SHL-7, SHL-24, and SHM-93-24A had slight exceedances of calcium, potassium, magnesium, manganese, and sodium. In addition, well SHL-6 had a slight

exceedance of lead (4.34 μg/L versus 4.25 μg/L); well SHL-7 had a slight exceedance of copper (8.35 μg/L versus 8.09 μg/L); and well SHL-24 had exceedances of arsenic (20.4 μg/L versus 10.5 μg/L), and zinc (36.8 μg/L versus 21.1 μg/L). Well SHL-12, located between SHL-17 and SHL-25, had exceedances of arsenic (31.6 μg/L versus 10.5 μg/L), lead (8.46 μg/L versus 4.25 μg/L), and zinc (30 μg/L versus 21.1 μg/L).

Unfiltered samples from downgradient monitoring wells typically exceeded background concentrations for arsenic, calcium, iron, potassium, magnesium, and manganese. In addition, there were scattered exceedances of background concentrations for barium, lead, vanadium, and zinc. Aluminum, copper, chromium, and nickel exceeded background once in monitoring well SHL-10, and antimony exceeded background in monitoring wells SHL-3 and SHL-11. All of these inorganics are considered contaminants in groundwater at Shepley's Hill Landfill. The highest concentrations of inorganics were found in monitoring wells SHL-10, SHL-11, SHL-19, SHL-20, and SHM-93-22C. The concentration of arsenic ranged between 69 and 390 μg/L in unfiltered samples from these wells. The unfiltered primary sample from monitoring well SHL-10 also showed high concentrations of chromium while its duplicate did not (115 versus 28 μg/L), nickel (177 versus < 34.3 μg/L), and lead (66.8 versus 14.9 μg/L).

Within the northern cross-gradient group, monitoring well SHL-8S exceeded the background concentration for manganese (1,590 μg/L versus 291 μg/L); well SHL-8D exceeded the background concentration for calcium (15,400 μg/L versus 14,700 μg/L) and manganese (712 μg/L versus 291 μg/L); well SHL-13 exceeded the concentration for arsenic (17 μg/L versus 10.4 μg/L), sodium (17,300 μg/L versus 10,800 μg/L), and lead (7.38 μg/L versus 4.25 μg/L); and well SHL-21 exceeded the concentration for arsenic (14 μg/L versus 10.5 μg/L) and lead (4.88 μg/L versus 4.25 μg/L).

SHL-15 was found to be contaminated with inorganics, especially arsenic, cadmium, copper, lead, and zinc during the RI sampling. However, samples collected during the supplemental RI showed substantially lower contaminant concentrations. Only arsenic (24 μg/L), calcium (15,600 μg/L), potassium (3,260 μg/L), manganese (1,430 μg/L), and zinc (35.8 μg/L) exceeded Fort Devens background concentrations in the Round 1 Supplemental RI groundwater sampling.

Well SHL-23, located at the northwest corner of the landfill, exceeded background potassium and zinc concentrations (3,550 μg/L versus 2,370 μg/L and 57.7 μg/L versus 21.1 μg/L, respectively).

The inorganics data obtained during Round 2 exhibited only minor variation from the Round 1 data for wells SHM-93-01A, SHM-93-10C, SHM-93-18B, and SHM-93-22C. The Round 2 sample from SHM-93-24A has consistently higher inorganic concentrations than the Round 1 sample. However, it also had a high TSS concentration (151 mg/L). Inorganic concentrations tended to drop markedly in the filtered sample from well SHM-93-24A, indicating that the inorganics were associated with the suspended solids.

Groundwater concentrations of the anions bromide, chloride, fluoride, nitrate, nitrite, and sulfate were measured during RI sampling conducted by E&E. The RI report concluded that monitoring wells SHL-4, SHL-11, SHL-19, and SHL-20 had elevated concentrations of chloride and bromide (E&E, 1993). Bromide was also noted in monitoring wells SHL-5 and SHL-22.

Comparison of dissolved (i.e., passing a 0.45 μ filter) inorganic concentrations with total inorganic concentrations from unfiltered samples enables assessment of the effect that TSS have on total metal concentrations. The effect was strongest on aluminum. Aluminum concentrations typically ranged from a few hundred to a few thousand μg/L in unfiltered samples, but exceeded the Certified Reporting Limit (CRL) of 141 μg/L in only one of 15 filtered samples (236 μg/L at SHL-5). Chromium, copper, and lead concentrations also were typically close to or below CRLs in filtered samples, although reduction from unfiltered levels was less dramatic.

In the case of arsenic and iron, the correlation with TSS was poor. High TSS in the unfiltered sample from SHL-10 corresponded to a high total arsenic concentration (280 μg/L), while the concentration in filtered samples was below the CRL of 2.54 μg/L. Concentrations of arsenic in unfiltered samples from SHL-11, SHL-19, and SHL-20 were also high (330 to 390 μg/L) and remained high in the filtered samples (160 to 270 μg/L), exceeding the MCL of 50 μg/L in filtered and unfiltered samples from all three wells. The explanation is based on the effect of pH and Eh, which were measured during presampling well purging and are tabulated below.

WELL	Eh (millivolts)	pH (s.u.)	TSS (mg/L)	TOTAL ARSENIC (μg/L)	DISSOLVED ARSENIC (μg/L)
SHL-10	259	6.7	3210/1680	280/58.6	<2.54/<2.54
SHL-11	13	6.3	204	340	230
SHL-19	127	8.1	129	390	160
SHL-20	68	6.5	48	330	270

Notes: mg/L = milligrams per liter.

Low Eh favors the presence of dissolved arsenic as does high pH. Of the two, Eh probably has the dominant effect; however, the two conditions are not mutually exclusive. Dissolved arsenic species exist within a broad range of Eh and pH conditions. Although the measured Eh of the sample from SHL-19 was higher than the Eh of samples from SHL-11 and SHL-20, the competing influence of high pH still results in the presence of dissolved arsenic. A high TSS concentration, by itself, was not a reliable predictor of total or dissolved arsenic. Although not tabulated above, iron behaved similarly to arsenic in wells SHL-10, SHL-11, SHL-19, and SHL-20.

For inorganics such as calcium, magnesium, potassium, and sodium that form readily ionizable salts, dissolved and total concentrations tended to be close.

As introduced above, the sample from SHL-10 provides a good illustration of the effect of high suspended solids on inorganic concentrations. The TSS concentrations in primary and duplicate samples from SHL-10 were the highest of any Shepley's Hill Landfill groundwater samples at 3,210 and 1,680 mg/L, respectively, and the unfiltered samples contained the highest concentrations of aluminum, barium, cobalt, chromium, copper, nickel, lead, vanadium, and zinc measured during supplemental RI sampling. The concentrations of arsenic, iron, and magnesium were among the highest. However, concentrations were dramatically lower in the filtered samples. Concentrations of aluminum, arsenic, cobalt, chromium, copper, nickel, vanadium, and zinc were below the CRL in both

primary and duplicate filtered samples. Barium, iron, and lead dropped to near CRL concentrations.

The interpreted distribution of inorganic contamination is similar to the interpretation in the RI Report in that maximum contamination is typically located along the eastern edge of the landfill in the downgradient well group (E&E, 1993). Maximum detected concentrations of inorganics considered to be contaminants and the monitoring wells in which they were detected are listed below.

ANALYTE	MAXIMUM CONCENTRATION (Unfiltered Samples) (μg/L)	MAX. WELL
Aluminum	75,500/15,400*	SHL-10
Antimony	3.3	SHL-3
Arsenic	390	SHL-19
Barium	350/78.1*	SHL-10
Calcium	219,000	SHL-22
Chromium	115/28*	SHL-10
Copper	54	SHL-10
Iron	97,400	SHL-11
Lead	66.8/14.9*	SHL-10
Magnesium	24,000	SHL-22
Manganese	9650	SHL-20
Nickel	177/<34.3*	SHL-10
Potassium	31,800	SHM-93-22C
Vanadium	79.1/21.9*	SHL-10
Zinc	220/50.8*	SHL-10

Note:

*Concentrations in primary and duplicate sample
< = less than

Because of the potentially transient nature of groundwater quality at Shepley's Hill Landfill and extensive well development/redevelopment intended to enable collection of representative groundwater samples, the supplemental RI samples are considered a better representation of groundwater quality than the RI samples.

4.1.2 Plow Shop Pond Sediments

Sediment sampling was conducted in Plow Shop Pond to better characterize the nature and extent of metals and pesticide contamination identified during the RI.

Useful data for assessing contamination in Plow Shop Pond sediments were obtained during supplemental RI activities from samples collected at 25 locations at multiple depths (locations SHD-92-01X through SHD-92-25X) using vibratory coring techniques, and three shallow sediment samples collected with an Ekman dredge as part of the macroinvertebrate study (locations SHD-92-26X through SHD-92-28X) (see Figure 2-1). All the samples were analyzed for PAL inorganics as well as PAL pesticides and PCBs and TOC. As described in Subsection 2.1.1 samples from SHD-92-01X through SHD-92-25X were collected from the 0-to-1-foot interval, at the bottom of the core, and at the midpoint of the core if more than 3 feet of core was recovered (ABB-ES, 1993a).

Table 4-5 summarizes the sediment analytical results.

Low concentrations of the pesticides, 2,2-bis(para-chlorophenyl)-1,1-dichloroethane (DDD), 2,2-bis(para-chlorophenyl)-1,1-dichloroethene (DDE), and 2,2-bis(para-chlorophenyl)-1,1-trichloroethane (DDT) were reported in six of 28 shallow sediment samples and in one 2-foot deep and one 5-foot deep sediment sample. Maximum and average detected concentrations of these contaminants in shallow sediments are listed below. Concentrations in the two deeper samples were approximately one order of magnitude less than the average shallow concentrations.

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM CONCENTRATION (μg/g)	AVERAGE DETECTED CONCENTRATION (μg/g)
DDD	4/28	1.8	0.57
DDE	5/28	1.3	0.32
DDT	1/28	0.13	0.13

Note: μg/g = micrograms per gram

These three compounds have been reported in sediment and soil samples collected from several Fort Devens sites, and they appear to represent widespread, low-level contamination. The compounds DDE and heptachlor were reported in one Plow Shop Pond sediment sample during the RI. There is no indication that Shepley's Hill Landfill is the source of these pesticides.

The RI report identified several SVOCs as contaminants in Plow Shop Pond sediments. The RI report did not associate the SVOCs with the landfill, but did list three other possible sources: Grove Pond, railroad ties, or former coal storage piles (E&E, 1993). SVOCs were not target analytes during supplemental investigations. The SVOCs interpreted as contaminants by E&E are listed below.

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM CONCENTRATION (μg/g)
Benzo(a)anthracene	1/13	1.10
Chrysene	1/13	1.50
Fluoranthene	1/13	3.40
Naphthalene	1/13	1.60
Phenanthrene	1/13	2.50
Pyrene	3/13	4.35

Source: E&E, 1993; Concentrations from IRDMIS, June 1993.

Review of the supplemental RI sediment data shows the widespread presence of several inorganics. Comparison of data for shallow sediment samples with data for the deeper samples shows that inorganic concentrations typically decrease by one and often by two orders of magnitude with increasing depth. Samples collected at locations SHD-92-13X and SHD-92-16X illustrate this well (see Table 4-5). At SHD-92-13X, arsenic concentrations range from 340 to 12.7 $\mu g/g$, chromium concentrations range from 5,250 to 71.9 $\mu g/g$, mercury concentrations range from 89 to 0.478 $\mu g/g$, and lead concentrations range from 160 to 7.76 $\mu g/g$. Similar reductions occur at SHD-92-16X and for copper, nickel, and zinc as well. In contrast to this, the data sets for sample locations SHD-92-03X, SHD-92-08X, SHD-92-10X, SHD-92-18X, and SHD-92-22X each contain examples of inorganics that are reported at higher concentrations with increasing depth. Typically this is true for some, but not all of the reported inorganics in the sample. This is attributed to the nonhomogeneity of sampled media and variability in laboratory analysis. The observation of low concentrations in the surface interval sample at location SHD-92-10X is consistent with observation of low concentrations in RI sample SE-SHL-07 collected nearby. ABB-ES does not have data to explain this, however. ABB-ES' overall interpretation of the sediment data is that inorganic contamination of the sediment resulted from transfer from the overlying water column and that surface interval concentrations are greater than concentrations at increasing depth. Figures 4-1 through 4-10 show distribution plots of arsenic, barium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc concentrations in supplemental RI shallow sediment data prepared using Quicksurf Version 3.03 (Schreiber Instruments, Inc., Denver, Colorado). The figures show distribution patterns that vary among the plotted inorganics and suggest different and sometimes multiple sources of contaminants. Each of the 10 plotted inorganics is discussed separately below.

Arsenic. Arsenic concentrations are highest along the western shore of Plow Shop Pond and in a broad band extending northwest across the pond from the railroad culvert. Concentrations in shallow (0-to-1-foot) sediments exceed the USEPA Region V sediment criterion of 3 $\mu g/g$ in all samples. Arsenic concentrations range between approximately 100 $\mu g/g$ and 500 $\mu g/g$ within these two areas. A narrow band with relatively low arsenic concentrations separates these areas. Figure 4-1 suggests two separate sources of arsenic. The first source is Shepley's Hill Landfill. This hypothesis is supported by the fact that arsenic concentrations in groundwater samples collected along the eastern edge of the landfill, adjacent

to Plow Shop Pond were the highest of those reported at the landfill. The second source is believed to be contaminated inflow from Grove Pond. Sediment samples collected in Grove Pond show arsenic concentrations as high as 910 μg/g in the northwest cove of Grove Pond adjacent to the railroad causeway. One possible source of this arsenic is a tannery known to have discharged waste to the pond in the 1940s and 1950s.

Arsenic was detected in all 13 of the samples collected during the RI. The highest concentrations, up to 3,200 μg/g, were reported in samples from the large cove along the western shore of the pond.

Barium. Barium concentrations ranged from below the CRL of 5.18 μg/g to 344 μg/g in Plow Shop Pond shallow (0-to-1-foot) sediments. Twenty-four of 28 samples exceeded the USEPA Region V sediment criterion of 20 μg/g. Concentrations were highest along the western shore of the pond, especially the small cove at the southwest edge of the pond (sample SHD-92-02X). Figure 4-2 suggests that Shepley's Hill Landfill is the primary source of barium contamination in pond sediments.

Barium was detected in all 13 of the samples collected during the RI at concentrations up to 310 μg/g. The pattern of concentration distribution among the RI samples is not clear, concentrations were distributed relatively evenly among the analyzed samples.

Chromium. Chromium concentrations in Plow Shop Pond shallow (0-to-1-foot) sediments ranged from below the CRL of 4.05 μg/g to 6,170 μg/g. Twenty-six of 28 samples exceeded the USEPA Region V sediment criterion of 25 μg/g. Although Figure 4-3 suggests the possibility of a minor contribution from Shepley's Hill Landfill (see samples SHD-92-02X and SHD-92-27X), the highest concentrations are distributed in a broad band extending northwest from the railroad culvert, suggesting a significant Grove Pond source. This is consistent with the former presence of the tannery on Grove Pond and chromium concentrations in Grove Pond sediment of more than 2.6 percent (26,100 μg/g) (see Subsection 4.2).

Chromium was detected at up to 10,000 μg/g in 11 of 13 samples collected during the RI. Highest concentrations were reported along the eastern side of the pond, supporting the theory of a Grove Pond source.

Copper. Copper concentrations ranged from below the CRL of 0.965 μg/g to 105 μg/g in Plow Shop Pond shallow (0-to-1-foot) sediments. The USEPA Region V sediment criterion of 25 μg/g was exceeded by 11 of 28 samples. Highest concentrations were clustered in the southeast quadrant of the pond, including the small southwest cove (sample SHD-92-02X). Figure 4-4 suggests that the primary source of copper to Plow Shop Pond is along the southern or eastern shore of the pond, and not the landfill.

Copper was detected at up to 132 μg/g in 9 of 13 RI samples. Concentrations were highest along the eastern shore of the pond supporting the theory of a source along the southern or eastern pond shore. (E&E concluded in the RI report that inflow from Grove Pond was the source of copper in Plow Shop Pond sediments.)

Iron. Iron concentrations ranged from 428 μg/g to 68,400 μg/g in Plow Shop Pond shallow (0-to-1-foot) sediments with an average of 19,100 μg/g. Eleven of 28 samples exceeded the USEPA Region V sediment criterion of 17,000 μg/g. Figure 4-5 shows that the highest concentrations are located along the western shore of Plow Shop Pond, indicating that Shepley's Hill Landfill is a major contributor of iron to the pond sediments. However, a second area of contamination exists in the center of the pond similar to the distribution pattern for chromium. High sediment iron concentrations in the northwest cove of Grove Pond confirm the potential for inflow from that pond to have contributed to high iron concentrations in Plow Shop Pond.

Iron was detected in all 13 RI sediment samples. Concentrations were highest, up to 330,000 μg/g, at the large cove along the western shore of the pond. This supports the theory that Shepley's Hill Landfill is a contributor of iron to pond sediments.

Lead. Concentrations of lead ranged from below the CRL of 1.77 μg/g in shallow (0-to-1-foot) sediment sample SHD-92-10 along the northwest shore of the pond to 260 μg/g in SHD-92-11 near the southeast edge of the pond. Fourteen of 28 samples exceeded the USEPA Region V criterion of 40 μg/g. High concentrations of lead along the southern edge of the pond as well as the broad band of high concentrations across the center of the pond (Figure 4-6), suggest Grove Pond and, to a lesser extent, a source along the southern or eastern shore of the pond. Sediment lead concentrations up to 390 μg/g in Grove Pond confirm

the potential for lead contamination to have migrated from Grove Pond (see Subsection 4.2).

Lead was detected in all 13 RI sediment samples. Concentrations ranged from 31 to 612 $\mu g/g$ and were highest in samples from the eastern half of the pond. E&E concluded in the RI report that inflow from Grove Pond was the source of lead in Plow Shop Pond sediments.

Manganese. Concentrations of manganese ranged from below the CRL at SHD-92-10X to 54,800 $\mu g/g$ at SHD-93-02X at the southwest cove in Plow Shop Pond. In general, concentrations along the western shore were the highest (970 $\mu g/g$ to 54,800 $\mu g/g$), and Figure 4-7 suggests that Shepley's Hill Landfill is the major source of manganese. Twenty-two of 28 samples exceeded the USEPA Region V sediment criterion of 300 $\mu g/g$.

Manganese was detected in all the RI sediment samples at concentrations up to 8,800 $\mu g/g$. Concentrations were highest at the mouth of the large cove along the western shore and near the northwest outlet of the pond, supporting the theory that the landfill is a source of manganese.

Mercury. Concentrations of mercury ranged from below the CRL of 0.05 $\mu g/g$ to 89 $\mu g/g$ in shallow (0-to-1-foot) sediment. The Ontario Ministry of the Environment sediment criterion of 0.1 $\mu g/g$ was exceeded in 24 of 28 samples. As shown in Figure 4-8, concentrations were highest in two areas near the middle of the pond, closely approximating the broad band of contamination observed for arsenic and chromium. This suggests an upstream, Grove Pond source. Mercury concentrations of up to 420 $\mu g/g$ in the northwest cove of Grove Pond confirm the potential for contaminants to have migrated from there to Plow Shop Pond. Concentrations along the western shore were below the CRL at SHD-92-01X and SHD-92-10X. Although mercury was reported at 16 $\mu g/g$ in SHD-92-02X from the small cove at the southwest of the pond, mercury was not reported in groundwater samples collected downgradient of the landfill, and there is no indication that the landfill is a current or past source of mercury contamination.

Mercury was detected in all RI sediment samples at concentrations of up to 130 $\mu g/g$. The highest concentrations were reported along the eastern shore of the pond, especially near the outlet culvert from Grove Pond. E&E concluded in

the RI report that inflow from Grove Pond was the source of mercury in Plow Shop Pond sediments.

Nickel. Concentrations of nickel in Plow Shop Pond shallow sediment ranged below the CRL of 1.71 $\mu g/g$ at several locations in the western part of Plow Shop Pond to 70.1 $\mu g/g$ at SHD-92-02X in the small southwest cove. Eleven of 28 samples exceeded the USEPA Region V sediment criterion of 20 $\mu g/g$. The distribution pattern for nickel is very similar to that for barium, and Figure 4-9 suggests that Shepley's Hill Landfill is the primary source of nickel in Plow Shop Pond sediments.

Nickel was detected in 9 of 13 RI samples at concentrations up to 79.3 $\mu g/g$. Among the RI samples, concentrations were highest in eastern half of the pond.

Zinc. Zinc concentrations ranged from below the CRL of 8.03 $\mu g/g$ to 403 $\mu g/g$ in shallow Plow Shop Pond sediment. Twelve of 28 samples exceeded the USEPA Region V criterion of 90 $\mu g/g$. High concentrations of zinc along the southern edge of the pond, as well as the broad band of high concentrations across the center of the pond (Figure 4-10) suggest Grove Pond and, to a lesser extent, a source along the southern or eastern shore of the pond. Sediment zinc concentrations up to 447 $\mu g/g$ in Grove Pond confirm the potential for zinc contamination to have migrated from Grove Pond.

Zinc was reported in only one RI sample, at 42.8 $\mu g/g$ in a sample from along the western shore of the pond.

Distribution plots were not prepared for the remaining detected inorganics. These chemicals were generally detected less frequently or had less well defined distribution patterns than the plotted chemicals. With the exception of cadmium, USEPA Region V and Ontario Ministry of the Environment criteria also were not available.

Aluminum. Aluminum was detected in all 28 shallow sediment samples collected during supplemental RI activities. Concentrations ranged from 388 to 13,185 $\mu g/g$. The highest concentration was reported in sample SHD-92-27X along the southwest shore of Plow Shop Pond and the lowest concentration was reported at SHD-92-10X, near the western shore of the pond. Several other high concentrations were detected in the central part of the pond. Aluminum was

detected at concentrations ranging from 963 to 24,000 μg/g in the 13 samples collected during the RI, and concentrations were highest in the central and eastern part of the pond.

Beryllium. Beryllium was not detected in shallow sediment samples collected during supplemental RI activities. It was detected in 8 of 13 samples collected during the RI at concentrations of up to 2.72 μg/g. The highest concentrations were reported in the eastern half of the pond. Beryllium was not detected in samples from the large cove along the western side of the pond.

Cadmium. Cadmium was detected above the CRL of 0.07 μg/g only in the sample from location SHD-92-06X (19.2 μg/g). This is in marked contrast with the RI data in which cadmium was reported for 12 of 13 samples and had a maximum concentration of 60 μg/g. Cadmium was detected only sporadically in groundwater during the RI, and was not detected during the supplemental RI sampling and analysis. The groundwater data thus do not support the theory that the landfill is a source of cadmium contamination or the expectation that cadmium should be detected in Plow Shop Pond sediments. ABB-ES interprets this to indicate that cadmium is in fact not a contaminant in Plow Shop Pond sediments.

Calcium. Calcium was reported in all 28 shallow sediment samples at concentrations ranging from 1,190 to 20,100 μg/g. Calcium was detected in 11 of 13 samples collected during the RI at approximately similar concentrations. Several of the highest concentrations were observed in the western half of the pond; however, low concentrations were interspersed with them making a distribution pattern unclear.

Cobalt. Cobalt was detected at concentrations up to 58.7 μg/g in 8 of 28 shallow sediment samples collected during supplemental RI activities. Although the detections appear to cluster in the southeast quadrant of the pond, they are interspersed with nondetect samples and a definite distribution pattern is not clear. Cobalt was not detected in samples collected during the RI.

Potassium. Potassium was found at up to 817 μg/g in 4 of 28 samples collected during supplemental RI activities. It was detected in all samples collected during the RI at concentrations up to 2,350 μg/g. There is no clear distribution pattern.

Sodium. Sodium was reported in all 28 shallow sediment samples collected during supplemental RI activities at concentrations of up to 2,870 $\mu g/g$. It was detected in at concentrations of up to 896 $\mu g/g$ in 7 of 13 samples collected during the RI. Concentrations appear to be highest in the center of the pond.

Magnesium. Magnesium was detected at concentrations up to 2,120 $\mu g/g$ in 23 of 28 shallow sediment samples collected during supplemental RI activities, and in 13 of 13 samples collected during the RI at concentrations of up to 6,900 $\mu g/g$. The distribution pattern is not clear.

Selenium. Selenium was detected at concentrations up to 6.62 $\mu g/g$ in 12 of 28 shallow sediment samples collected during supplemental RI activities. Detections appear to cluster in the eastern half of the pond; however, several nondetects were interspersed among them, making the distribution pattern unclear. Selenium was not detected in samples collected during the RI.

Vanadium. Vanadium was reported at concentrations up to 61.7 $\mu g/g$ in 6 of 26 samples collected during supplemental RI activities. Detections appear to cluster in the southeastern quadrant of the pond; however, several nondetects are interspersed among them, making the distribution pattern unclear. Vanadium was detected in 9 of 13 samples collected during the RI. Among these samples, concentrations were highest in the eastern half of the pond. Vanadium was not detected in RI samples from the large cove along the western shore of the pond.

These interpreted distribution patterns and sources for contaminants detected in shallow sediments differ somewhat from the interpretations presented in the RI report (E&E, 1993). This is primarily attributable to collection of a greater number of samples (28 versus 13) and to a more uniform sample location distribution across the pond. During the RI, samples were collected primarily along the pond shoreline. Table 4-6 compares the interpreted sources of Plow Shop Pond sediment contamination. The major differences between the initial and supplemental RI interpretations are listed below:

- Although Shepley's Hill Landfill remains an active source of arsenic contamination, the major historical source is interpreted to be inflow from Grove Pond. Grove Pond inflow is considered responsible for the large area of arsenic contamination in the middle of Plow Shop Pond.

- Inflow from Grove Pond is potentially the major historical source of chromium and lead contamination in Plow Shop Pond. Shepley's Hill Landfill may have been a minor source of chromium and lead to sediments at the southwest corner of Plow Shop Pond.

Table 4-7 compares frequency of detection, maximum concentrations, and average concentrations for the RI and Supplemental RI sediment data sets. Review of the table shows that inorganic concentrations were typically higher in the RI data set than in the supplemental data set. Several factors may have contributed to the differences between the data sets. These include different sampling locations combined with nonuniform areal distribution of inorganics across the pond bottom, nonhomogeneity of the sediment itself, differences in sampling methods, and variability of laboratory analysis. Of these, only the differing sampling methods would be predicted to result consistently in measurement of lower shallow sediment concentrations. The RI samples were collected from the upper few inches of the sediment with an Ekman dredge, while the supplemental RI samples were collected from the upper foot using vibratory coring techniques. Because the supplemental RI data indicate that sediment inorganic concentrations decrease with depth, the Ekman dredge samples might be expected to contain higher concentrations of inorganics than 0-1 foot depth core samples. Sufficient data are not available, however, to confirm this theory or quantify an actual effect. The vibratory coring technique is thought to have collected less disturbed samples (i.e., samples more representative of the given depth interval) than the Ekman dredge.

TCLP extracts were prepared for seven Plow Shop Pond sediment samples and analyzed for the eight RCRA metals to aid in evaluating remedial alternatives during the FS.

Concentrations of the eight metals in the extracts were well below regulatory thresholds designating the characteristic of toxicity (Table 4-8).

Table 4-9 lists chemicals exceeding groundwater and sediment evaluation criteria in Shepley's Hill Landfill groundwater and Plow Shop Pond sediments.

4.1.3 Plow Shop Pond Surface Water

ABB-ES did not collect Plow Shop Pond surface water samples during supplemental RI activities. However, E&E collected 13 samples during the RI and the data were presented in the RI report (E&E, 1993). The samples were analyzed for Target Compound List (TCL) organics, Target Analyte List (TAL) metals and several general analytical parameters.

The VOCs methylene chloride and chloroform and the pesticides alpha-benzenehexachloride and endrin were the only organic compounds reported in the samples. The methylene chloride, alpha-benzenehexachloride, and endrin were attributed to laboratory contamination. Although its presence was considered suspect, E&E could not account for the chloroform as laboratory contamination.

Table 4-10 summarizes the surface water data for TCL organics and TAL metals. Surface water background data are not available for comparison to identify inorganic contaminants. The data are discussed further and compared to AWQC in the ecological risk assessment of Section 7.0.

4.1.4 Landfill Gas Monitoring

Landfill gas samples were collected from 21 location at Shepley's Hall Landfill to assess whether landfill gas may be migrating offsite (see Subsection 2.1.5). The results of the monitoring are presented in Table 4-11. Review of the data shows that only two (benzene and methane) of the 20 target analytes were detected in the gas samples. Benzene was detected in samples SG-10 and SG-11 located at the western edge of the landfill near well SHL-1 and in Vent Sample 2 and Vent Sample 5. Detected concentrations ranged from 1.0 to 11 μg/L (vapor). All four samples were from locations within Phase 1 of the landfill closure.

Methane was detected in seven of 16 gas probe samples and in four of five gas vent samples. The maximum detected concentration was 110,000 μg/L (vapor) in sample SG-10. Landfill gases were not detected at five gas probe locations (SG-1 through SG-5) spaced at approximate 100 ft intervals along the northeast edge of the landfill.

The data indicate that methane is being generated within the landfill and is moving laterally from beneath the membrane cap along the eastern edge of the

landfill. The distance of migration was not determined. Ambient air monitoring during E&E's RI did not detect methane at the landfill.

Data from gas probe locations SG-1 through SG-5 indicate that landfill gas is not migrating toward residences on Sully Street northwest of the landfill.

The detection of benzene in four gas samples indicates a source of benzene within the landfill, and is consistent with its detection in several groundwater samples. Ambient air monitoring during E&E's RI did not detect benzene at the landfill.

4.2 Grove Pond Surface Water and Sediment

Grove Pond is located immediately upstream of Plow Shop Pond and is of interest because of the potential for contaminants to have migrated from Grove Pond to Plow Shop Pond in the past and to continue to migrate in the future. This subsection assesses contamination in samples collected at the western end of Grove Pond by ABB-ES personnel in December 1992 and January 1993.

4.2.1 Grove Pond Surface Water

Five surface water samples were collected in Grove Pond and analyzed for PAL VOCs, SVOCs, pesticides and PCBs, explosives, inorganics, TOC, alkalinity, TDS, TSS, hardness, and alkalinity (see Figure 2-9). Table 4-12 summarizes the analytical results. Except for trichloroethylene at 0.5 μg/L in sample GRW-92-04X, no PAL organics were reported.

A total of 10 PAL inorganics were detected with the highest concentrations for seven reported in GRW-92-04X (aluminum, 2,960 μg/L; arsenic, 4.05 μg/L; barium, 42.3 μg/L; calcium, 19,700 μg/L, iron, 841 μg/L, lead, 6.18 μg/L; potassium, 2,730 μg/L). Surface water background concentrations are not available for comparison; however, comparison of the reported values with Ambient Water Quality Criteria (AWQC) for protection of aquatic life reveals that criteria have only been established for three of the detected inorganics: aluminum, iron, and lead. No exceedances of AWQC were observed for samples GRW-92-02X and GRW-92-03X. Sample GRW-92-01X exceeded the chronic criteria for lead (2.06 μg/L versus 1.3 μg/L, assumed hardness of 50 mg $CaCO_3$/L), but not the acute criteria (34 μg/L). Sample GRW-92-04X exceeded

the chronic and acute criteria for aluminum (2,960 μg/L versus 87 and 750 μg/L, respectively) and chronic criteria for lead (6.18 μg/L versus 1.3 μg/L, assumed hardness of 50 mg $CaCO_3$/L), but not the acute criteria (34 μg/L). Sample GRW-92-05X exceeded the chronic criteria for lead (4.23 μg/L versus 1.3 μg/L, assumed hardness of 50 mg $CaCO_3$/L).

Based on the above comparisons, it appears that surface water in the western end of Grove Pond is not heavily contaminated.

4.2.2 Grove Pond Sediment

Five shallow sediment samples were collected in Grove Pond and analyzed for PAL VOCs, SVOCs, pesticides and PCBs, inorganics, and TOC (see Figure 2-9). Review of the data in Table 4-13 indicates the presence of VOCs, acetone in four of five samples, and toluene in one sample at concentrations of less than 1 μg/g. Toluene was also found in five of 21 rinsate blanks at concentrations up to 4.2 μg/L, and consequently it is not considered a sediment contaminant (see Appendix H). A total of 10 SVOCs were detected in samples GRD-92-02X, GRD-92-03X, and GRD-92-04X. The greatest number (nine) of SVOCs were reported in GRW-92-04X with a total concentration of 12.8 μg/g. This distribution of organic contaminants suggests a source upstream of GRD-92-04X, possibly associated with railroad activities. The SVOC 4-methylphenol was reported at 12 μg/g and 17 μg/g in GRD-92-02X and GRD-92-03X, respectively, but not in GRD-92-04X, thus suggesting a different source for this compound. The pesticides DDD, DDE, and DDT were reported in sediment samples at concentrations of up to 0.15 μg/g. The highest concentrations were detected in the sample collected at GRD-92-04X.

A total of 19 PAL inorganics were detected in Grove Pond sediments. Review of the data indicates that the highest concentrations of 16 of the 19 were found in either GRW-92-02X or GRW-92-03X at the northwest corner of Grove Pond. These included arsenic (910 μg/g), chromium (26,100 μg/g), copper (98.6 μg/g), and mercury (420 μg/g) in GRD-92-03X and aluminum (10,900 μg/g), barium (181 μg/g), iron (25,400 μg/g), nickel (36.9 μg/g), lead (390 μg/g), and zinc (447 μg/g) in GRD-92-02X. Arsenic, chromium, copper, lead, manganese, nickel, and zinc exceeded USEPA Region V sediment criteria in either one or both of GRD-92-02X and GRD-92-03X. Sample GRD-92-02X exceeded the Ontario Ministry of the Environment criterion for cadmium. Samples GRD-92-01X,

GRD-92-02X, and GRD-92-03X exceeded the Ontario Ministry of the Environment criterion for mercury. Grove Pond sediments, particularly those in the northwest cove, appear heavily contaminated with these inorganics. The presence of arsenic, chromium, lead, and mercury and potentially other inorganics may be associated with waste disposal practices at the former tannery located near the northwest corner of Grove Pond.

4.3 NONACOICUS BROOK WETLAND SHALLOW GROUNDWATER AND SOIL

The Data Gap Activities Work Plan proposed collection of surface water and sediment samples to better characterize the nature and extent of contamination in the area north of Shepley's Hill Landfill. An additional goal was to evaluate whether the area is a discharge area for contaminated groundwater migrating from beneath the landfill. A lack of standing water in the area at the time of sampling necessitated collecting groundwater samples from shallow, 2-to-3-foot deep pits. In addition, field observations indicate that the term "soil" more accurately describes the solids collected than "sediment". This section discusses the results of the sampling.

4.3.1 Nonacoicus Brook Wetland Shallow Groundwater

Groundwater samples were collected from four shallow (2.5-to-3-foot deep) pits and were analyzed for PAL VOCs, pesticides and PCBs, explosives, total and dissolved inorganics, TOC, alkalinity, TDS, and TSS (see Figure 2-2). Review of the analytical data in Table 4-14 shows that no PAL organics were detected in the samples.

Comparison of analytical data for inorganics with Fort Devens background concentrations shows that samples from SHW-92-01X and SHW-92-02X, located near Nonacoicus Brook, did not exceed background concentrations for any inorganics. However, unfiltered samples from SHW-92-03X and SHW-92-04X, both located north of the landfill, exceeded background concentrations for 14 of 15 reported inorganics including arsenic (up to 24.9 μg/L), barium (up to 136 μg/L), chromium (up to 32.7 μg/L), copper (up to 19 μg/L), mercury (up to 0.866 μg/L), and lead (up to 81.7 μg/L).

Review of the dissolved inorganic data for the samples shows the effect of high sample TSS (104 and 8,440 mg/L at SHW-92-03X and SHW-92-04X, respectively) on inorganic concentrations. The data for dissolved inorganics show background exceedances only for barium (up to 67 μg/L), calcium (up to 25,900 μg/L), potassium (up to 2,530 μg/L), manganese (up to 417 μg/L), lead (up to 5.53 μg/L), and zinc (up to 160 μg/L).

Whereas the inorganic concentrations in unfiltered samples from SHW-93-03X and SHW-93-04X typically exceeded the concentrations in unfiltered samples from wells SHL-9 and SHL-5 located between SHW-93-03X and SHW-93-04X and the landfill, concentrations in filtered samples are comparable to filtered samples from SHL-5 and SHL-9. The conclusion of this comparison is that high inorganic concentrations in samples from SHW-92-03X and SHW-92-04X result from high TSS concentrations, and that the dissolved contaminant load being transported by groundwater is low. Barium, calcium, potassium, manganese, lead, and zinc are considered contaminants in shallow groundwater.

4.3.2 Nonacoicus Brook Wetland Soil

A total of eight soil samples were collected at four locations (SHD-92-29X through SHD-93-32X) in the area north of the landfill and analyzed for PAL VOCs, pesticides and PCBs, explosives, inorganics, and TOC (see Figure 2-2). Samples were collected at the surface (0 to 6 inches bgs) and at 1 or 2 feet bgs at each location. Table 4-15 summarizes the analytical results. No PAL VOCs or explosives were reported in any samples. Low concentrations (up to 0.17 μg/g) of the pesticides DDE and DDT were reported in the surface and 1 foot bgs intervals at SHD-92-31X and SHD-92-32X.

A total of 20 PAL inorganics were detected in the eight samples. Antimony, cadmium, and thallium were not detected. Comparison of the analytical data with Fort Devens background soil concentrations shows that of those detected, 16 (all but aluminum, magnesium, potassium, and vanadium) exceeded background concentrations at least once. Chromium and mercury were found at the highest concentrations at SHD-92-29X (89.5 μg/g and 1.9 μg/g, respectively) and SHD-92-30X (51 μg/g and 0.966 μg/g, respectively). Arsenic, beryllium, calcium, cobalt, copper, manganese, and nickel were found at the highest concentrations in the surface (0-to-6-inch) interval sample at SHD-92-31X. Concentrations in this sample, however, were typically well below values observed in Plow Shop Pond

sediment and in several cases were within the range of values used to estimate background. The highest concentrations of zinc were measured at sample location SHD-92-32X. Among the four sampling locations, surface interval samples had a greater number of exceedances than subsurface samples.

The available data indicate that soils adjacent to Nonacoicus Brook may be contaminated with chromium and mercury. The elevated concentrations of chromium and mercury in shallow soil samples at locations SHD-93-29X and SHD-92-30X, adjacent to Nonacoicus Brook, suggests that historical brook overflows were their source. This conclusion is consistent with the interpretation that contaminated surface water was the source of high concentrations of chromium and mercury found in Plow Shop Pond sediments. Beryllium and silver were each detected once in the eight samples, at concentrations that exceeded the 68th percentile upperbound. Copper and zinc exceeded 68th percentile upperbound limits at SHD-92-31X and SHD-92-32X. Although their frequency of detection was low, all four may represent contamination. The possible influence of Shepley's Hill Landfill is not clear, locations SHD-92-31X and SHD-92-32X have been and are subject to anthropogenic sources not limited to the landfill. Among the inorganics, chromium, mercury, beryllium, silver, copper, and zinc are considered contaminants in Nonacoicus Brook wetland soils.

TCLP extracts were prepared for shallow soil samples at SHD-92-29X and SHD-92-30X, and analyzed for eight RCRA metals to aid in potential evaluation of remedial alternatives during the FS. Only barium and chromium were reported in the extracts. The reported concentrations were well below regulatory thresholds indicating the characteristic of toxicity (Table 4-16).

Based on the following four factors, the area between the north end of the landfill and the railroad tracks is not considered a major discharge area for contaminated groundwater:

- Although the groundwater table is shallow in the area, standing water was not found during sampling and shallow pits had to be dug to obtain water samples.

- Downward or neutral vertical gradients rather than upward gradients were observed at well pairs SHL-22/SHM-93-22C and SHL-8S/SHL-8D.

- High concentrations of surface soil contaminants indicative of long-term discharge of contaminated groundwater were not observed.

- The presence of contaminants in shallow groundwater is largely associated with suspended solids, indicating that groundwater is not highly contaminated.

4.4 Cold Spring Brook Landfill

The assessment of contamination at Cold Spring Brook Landfill is of particular interest because of its proximity to Patton Well. This subsection discusses the results of supplemental sampling at the landfill. The discussion of inorganics in groundwater focuses first on data from unfiltered samples, followed by a discussion of factors that may modify the reader's interpretation.

4.4.1 Cold Spring Brook Landfill Groundwater

Groundwater samples were collected from 10 monitoring wells during Round 1 groundwater sampling at Cold Spring Brook Landfill and analyzed for PAL SVOCs, pesticides and PCBs, explosives, inorganics, TOC, alkalinity, TDS, and TSS, and from three monitoring wells during Round 2 (see Figure 2-8). A sample was also collected from well CSB-1 during Round 2 and analyzed for explosives only. In addition, samples from four of the Round 1 and one of the Round 2 wells were field filtered and analyzed for dissolved PAL inorganics. Field filtering and dissolved metals analysis was done to enable assessment of the contribution of suspended solids to total metal concentrations. The effect of field filtering is discussed at the end of this subsection. Table 4-17 summarizes the Round 1 analytical data.

Based on the hydrological interpretation of Subsection 3.4, monitoring wells CSB-1, CSB-3, CSB-6, CSB-7, and CSB-8 are either upgradient or cross-gradient of Cold Spring Brook Landfill. Although located close to the upgradient edge of the landfill, the boring log indicates that CSB-8 is not constructed in landfill materials. Well CSB-2 is downgradient, but is screened below the water table, and therefore may not be suitable for monitoring the potential migration of contaminants from Cold Spring Brook Landfill. Wells CSM-93-01A and

CSM-93-02B are also screened below the water table and monitor a similar region of the aquifer as CSB-2. Well CSM-93-02A is the only downgradient water table well located to monitor contaminant migration from the landfill. Well CSB-5 is located in peat and does not monitor a representative or productive aquifer.

Organics. The detection of PAL organics in Round 1 samples was limited to the SVOC bis(2-ethylhexyl) phthalate at 84 μg/L in well CSB-5 and at 14 μg/L in well CSM-93-02B. Bis(2-ethylhexyl)phthalate was undetected (i.e., <4.5 μg/L) in the three primary Round 2 samples, but was reported at 4.4 μg/L in the duplicate sample from well CSM-93-01A. No other organics, pesticides, PCBs, or explosives were detected in any of the sampled wells. These results contrast with analytical results obtained during the RI. During the RI, low concentrations of explosives were reported in well CSB-1 and low concentrations of pesticides were reported in several wells. Pesticides were also detected in several laboratory method blanks, thus raising doubt about their reported presence in field samples. The data collected during the supplemental RI indicate that neither explosives nor pesticides are present in groundwater. VOCs were not identified as groundwater contaminants in E&E's RI report and were not target analytes during supplemental RI activities.

Inorganics. A total of 16 PAL inorganics were detected in groundwater samples from the monitoring wells at Cold Spring Brook Landfill. Review of the Round 1 analytical data and comparison with Fort Devens groundwater background concentrations confirms the conclusion of the RI that monitoring well CSB-1, which is interpreted as upgradient of any landfill influence, may be affected by a further upgradient source. This is also true for CSB-3, CSB-6, and CSB-8. Concentrations of seven inorganics in CSB-1 exceeded calculated background concentrations and the concentrations of cobalt (35 μg/L) and zinc (90.6 μg/L) were the highest reported among the sampled wells. In the case of monitoring well CSB-7, which is cross-gradient and east of the landfill, the average concentration of arsenic and sodium in primary and duplicate samples slightly exceeded the background concentrations (10.7 μg/L versus 10.4 μg/L, and 14,550 μg/L versus 10,800 μg/L, respectively).

Unfiltered Round 1 samples from monitoring wells CSB-3 and CSB-6, located upgradient and south of the landfill, showed slight exceedances of aluminum, arsenic, barium, chromium, copper, lead, vanadium, and zinc. The unfiltered sample from CSB-8, however, exceeded background concentrations for 12 of the

inorganic analytes. The highest concentrations for seven of the 16 reported inorganics were in the sample from monitoring well CSB-8.

Monitoring well CSM-93-01A exceeded background concentrations for arsenic (25.9 μg/L versus 10.5 μg/L), barium, calcium, iron, potassium, magnesium, manganese, and sodium, while well CSM-93-02B exceeded the concentration for calcium, copper, potassium, magnesium, manganese, and sodium. Well CSB-2 exceeded background for calcium, potassium, magnesium, and manganese.

The sample from monitoring well CSM-93-02A showed exceedances for 11 inorganic analytes with concentrations very similar to those reported for CSB-8. The closeness of the values suggests a common influence. This potentially could be either a source located south of Patton Road or, most likely Patton Road itself. The hydrological interpretation is that the landfill does not influence CSB-8.

Inorganic concentrations were generally lower in the Round 2 samples than in Round 1 samples; however, values for several analytes continued to exceed 68th percentile background concentrations. The sample for CSM-93-01A exceeded background for arsenic, calcium, iron, potassium, magnesium, and manganese and the sample from CSM-93-02B exceeded background for calcium, potassium, magnesium, and manganese. The sample for well CSM-93-02A showed exceedances for 10 analytes, although all concentrations were less than in the Round 1 sample. Table 4-18 summarizes the Round 2 data.

Groundwater concentrations of the anions bromide, chloride, fluoride, nitrate, nitrite, and sulfate were measured during RI sampling conducted by E&E. The RI report concluded that monitoring wells CSB-1, CSB-2, CSB-6, and CSB-8 were affected by chloride and possibly sulfate, presumably from road salt applied to Patton Road (E&E, 1993).

Comparison of analytical results for filtered and unfiltered samples from CSB-2, CSB-3, CSB-8, CSM-93-01A, and CSM-93-02A shows a pattern similar to the pattern for Shepley's Hill Landfill groundwater (see Subsection 4.1): concentrations of aluminum, chromium, copper, and lead drop markedly in the filtered samples, usually to less than the CRL. This pattern is also displayed by zinc. Concentrations of the common ions calcium, magnesium, potassium, and sodium remained relatively constant in filtered and unfiltered samples. However, arsenic and iron behaved differently in Cold Spring Brook Landfill groundwater

samples than in samples from Shepley's Hill Landfill. Both arsenic and iron were associated predominantly with TSS at Cold Spring Brook Landfill. Dissolved concentrations were typically near or below the CRL. Total and dissolved arsenic concentrations are tabulated below, along with TSS and pH for the four wells where filtered samples were collected. Eh data were not collected at Cold Spring Brook Landfill.

WELL	pH (s.u.)	TSS (mg/L)	TOTAL ARSENIC ($\mu g/L$)	DISSOLVED ARSENIC ($\mu g/L$)
CSB-2	6.7	22	<2.54	<2.54
CSB-3	6.9	320	14.8	<2.54
CSB-8	6.3	2030	28	<2.54
CSM-93-01A	6.9	<40	25.9	6.4

Based on the distribution pattern for inorganics in the unfiltered samples and a comparison of data for filtered and unfiltered samples, the Cold Spring Brook Landfill is not considered to be a source of inorganic groundwater contamination.

A sample was also collected from Patton Well and analyzed for PAL VOCs, SVOCs, pesticides and PCBs, explosives, inorganics, TOC, TSS, TDS, and alkalinity. Table 4-17 summarizes the analytical results. No PAL organic compounds were detected. Several PAL inorganics were detected at concentrations above 68th percentile upperbound concentrations. These are listed below.

ANALYTE	PATTON ROAD SUPPLY WELL MEASURED CONCENTRATION ($\mu g/L$)	BACKGROUND CONCENTRATION ($\mu g/L$)	DRINKING WATER STANDARD ($\mu g/L$)
Calcium	43,400	14,700	None
Copper	20.0	8.09	1,300
Potassium	3,780	2,370	None
Magnesium	5,310	3,480	None
Sodium	12,000	10,800	28,000*

* Massachusetts guideline

The analytical results indicate that the Patton Well has good water quality. There is no indication that it is being influenced by Cold Spring Brook Landfill.

4.4.2 Cold Spring Brook Landfill Seeps

Although no active seep discharges or stained areas were observed at the time of sample collection, surface water samples were collected at two locations and a shallow groundwater sample was collected at a third location adjacent to Cold Spring Brook Landfill to help evaluate whether the landfill was a source of surface water contamination (see Figure 2-8). Sediment samples were collected at the same locations to aid in assessing the effect of potentially contaminated seeps/surface water. The sediment samples are discussed in Subsection 4.4.3.

Surface water sample CSW-92-01X was collected from an area of standing water that is seasonally isolated from Cold Spring Brook Pond and approaches dryness at the western end of the landfill. Approximately 1-foot of water was present at the time of sampling. Sample location CSW-92-02X was at the mouth of a small drainageway that discharges to the inlet channel to Cold Spring Brook Pond from the northwest.

Sample location CSW-92-03X was in the small valley between the landfill and peat mound adjacent to well CSB-4 and the water sample was collected from a shallow, 6-inch-deep pit. All samples were analyzed for PAL SVOCs, pesticides and PCBs, explosives, total and dissolved inorganics, TOC, TSS, TDS, and alkalinity. Table 4-19 summarizes the analytical data and Table 4-20 lists the frequency of detection and maximum concentration in unfiltered samples.

Organics. No SVOCs, explosives, or PCBs were reported in the samples. The pesticide DDD was reported at 0.081 μg/L in the sample from CSW-92-01X.

Inorganics. Review of the analytical data leads to two conclusions:

- Total metal concentrations in all three samples are strongly influenced by TSS.
- The sample from CSW-92-03X has a different character than the samples from the other two locations.

Samples from CSW-92-01X and CSW-92-02X showed high TSS concentrations (1,080 and 2,880 mg/L, respectively) and high total concentrations of barium, chromium, copper, nickel, lead, vanadium, and zinc that were typically reduced to near CRL or below CRL concentrations by filtration. In contrast, concentrations of the common ions calcium, magnesium, potassium, and sodium dropped only slightly. High arsenic and iron concentrations were reported in the unfiltered samples; however, dissolved concentrations were also high (270 and 96 μg/L, respectively) suggesting the presence of low Eh conditions that had mobilized the two elements. High arsenic and iron concentrations were reported in the unfiltered samples; however, dissolved concentrations were also high (270 to 96 μg/L, respectively) suggesting the presence of low Eh conditions that had mobilized the two elements. Although Eh was not measured at these locations, a rotten egg odor, indicative of low Eh conditions and observed at sediment sample location CSD-92-11X, corresponding to water sample location CSW-92-01X, suggests that low Eh conditions existed. The extent, if any, to which the landfill may have contributed to such conditions cannot be determined from the available data.

The sample from location CSW-92-03X showed unremarkable concentrations of inorganics in the unfiltered portion and still lower concentrations in the filtered

portion. The sample does not suggest that the landfill is a source of contamination.

4.4.3 Cold Spring Brook Pond Sediments

A total of 36 sediment samples (excluding duplicates) were collected from 16 locations at Cold Spring Brook Pond. These included 27 samples collected at up to three depths at 10 locations within the pond boundary using vibratory coring techniques, three shallow (0-to-6-inch) sediment samples collected at macroinvertebrate sample locations within the pond boundary, and six samples collected at 0-6 inch and 1 foot depths at landfill seep locations. To allow comparison of data with RI data, all the samples were analyzed for PAL SVOCs, pesticides and PCBs, explosives, inorganics, and TOC. Table 4-21 summarizes the supplemental analytical data. Table 4-22 compares frequency of detection and maximum and mean concentrations for the two data sets.

Organics. A total of 15 SVOCs were reported at four sediment sample locations: CSD-92-01X, CSD-92-02X located along Patton Road on opposite sides of the pond outlet, and at CSD-92-09X and CSD-92-14X located within approximately 60 feet of each other along the southwest pond shore. Four of the SVOCs were found only at CSD-92-09X while the remaining 11 were found almost exclusively at CSD-92-01X and CSD-92-02X. Only one SVOC was detected at CSD-92-14X. The highest SVOC concentrations were reported in the 2-foot-deep sample from CSD-92-01X; however, SVOCs were also reported for the 0- and-3-foot-deep samples at this location. SVOCs were reported in the 0-, 3-, and 5-foot-deep samples at CSD-92-09X. The detection of SVOCs near the pond outlet is consistent with the findings of the initial RI. SVOCs reported in RI sample SE-CSB-06 were not confirmed by CSD-92-06X or CSD-92-15X.

The pesticides DDD, DDE, and DDT were reported in 10 of 16 shallow sediment samples. Concentrations were typically below 1 $\mu g/g$, with the exception that DDD and DDT were reported at 6.07 $\mu g/g$ and 15.5 $\mu g/g$, respectively, at CSD-92-01X. Except for the CSD-92-01X sample, there was no distinct distribution pattern. No PCBs were detected in any sediment samples. The explosive nitroglycerine was reported at 11.3 $\mu g/g$ in CSD-92-14X, but in no other sediment samples. Because of its low frequency of detection, nitroglycerine is not considered a contaminant in sediments. The VOC 2-butanone was detected at a

low concentration (0.025 μg/g) in one sediment sample during RI sampling. VOCs were not target analytes during supplemental RI sampling.

Inorganics. A total of 20 PAL inorganics were reported in the sediment samples collected during supplemental RI activities; cadmium, mercury, and thallium were not detected. Table 4-23 compares the shallow sample data to the evaluation criterion of Table 4-2. Review of the table shows that arsenic exceeded the USEPA V sediment criterion in all 16 samples, barium exceeded the USEPA criteria in 9 of 16 samples and manganese exceeded the arsenic criterion in 8 of 16 samples. Chromium, copper, iron, lead, nickel, and zinc exceeded USEPA criteria five or fewer times. Although arsenic concentrations exceeded the arsenic criterion across the entire sampled area, the highest concentrations of arsenic and other inorganics are clustered along the southwest side of the pond at CSD-92-07X, CSD-92-08X, CSD-92-09X, and CSD-92-14X. An arsenic concentration of 910 μg/g was reported at CSD-92-07X. The 0-to-1-foot-deep sample at CSD-92-01X also contained high concentrations of arsenic (82 μg/g), barium (115 μg/g), iron (36,400 μg/g), and zinc (291 μg/g).

Comparison of the RI data to the evaluation criteria shows a similar pattern, arsenic, barium, and manganese exceeded the criteria most frequently. A notable difference between the data sets is that mercury was detected in 6 of 9 RI samples (the highest concentration was near the pond outlet), but was not detected in any of 16 supplemental samples.

Sediment samples from the three areas likely to be affected by leachate if it were present contained notably low inorganics concentrations compared to the remaining samples. Arsenic was reported at 78 μg/g to 99 μg/g at CSD-92-11X and at 20 μg/g to 22 μg/g at CSD-92-12X. Manganese was reported at 1,110 μg/g at CSD-92-11X. No other reported concentrations exceed the Region V evaluation criteria at CSD-92-11X, CSD-92-12X, and CSD-92-13X. Concentrations of the eight RCRA metals in TCLP extracts from five Cold Spring Brook Pond sediment samples were well below the regulatory thresholds designating the characteristic of toxicity (Table 4-24).

4.4.4 Cold Spring Brook Pond Surface Water

ABB-ES did not collect Cold Spring Brook Pond surface water samples during supplemental RI activities. However, E&E collected nine samples and presented

the data in the RI report (E&E, 1993). The samples were analyzed for TCL organics, TAL metals, explosives, and several general analytical parameters.

The only organic compounds reported in the samples were methylene chloride and the pesticide alpha-benzenehexachloride. These were also found in laboratory method blanks, and E&E attributed their presence to laboratory contamination.

Table 4-25 summarizes the surface water data for TCL organics and TAL metals. Surface water background data are not available for comparison to identify inorganic contaminants. The data are discussed further and compared to AWQC in the ecological risk assessment of Section 7.0.

Table 4-26 summarizes groundwater, sediment, and soil chemicals exceeding evaluation criteria at Cold Spring Brook Landfill.

4.5 Magazine Area Shallow Groundwater and Soil

The Data Gap Activities Work Plan proposed collection of surface water and sediment samples from the bed of the intermittent inlet stream to Cold Spring Brook Pond to characterize conditions upstream of the pond and possible contaminant sources within the Magazine Area. A lack of surface water in the streambed at the time of sampling necessitated collecting groundwater samples from shallow 2-3-foot-deep pits at two of three locations. Shallow groundwater was not available at a third location. ABB-ES personnel also collected soil samples from the shallow pits. The term "soil" is considered more accurate than "sediment", which was used to describe the proposed samples in the Data Gap Activities Work Plan (ABB-ES, 1993a). The groundwater/soil sample pair location MAW-92-03X/MAD-92-03X was located at the beginning of the streambed near the center of the Magazine Area. Sediment sample MAD-92-02X was located about 75 feet from the downstream edge of the Magazine Area, and sample pair MAW-92-01X/MAD-92-01X was located about 75 feet outside of the Magazine Area. This subsection discusses the results of the Magazine Area sampling. Tables 4-27 and 4-28 present the analytical results for Magazine Area samples.

4.5.1 Magazine Area Shallow Groundwater

Groundwater samples were collected from shallow pits at MAW-92-01X and MAD-92-03X and analyzed for PAL SVOCs, pesticides and PCBs, explosives, total and dissolved inorganics, TOC, alkalinity, TSS, and TDS (see Figure 2-8). Review of the data shows that the SVOC bis(2-ethylhexyl)phthalate and the pesticide DDD were reported at 17 and 0.024 μg/L, respectively, in the sample from MAW-92-01X. No SVOCs, pesticides or PCBs were detected in the sample from MAW-92-03X. Explosives were not detected in samples from either location.

Comparison of analytical data with Fort Devens background concentrations shows that 14 PAL inorganics were detected in the unfiltered groundwater samples. Concentrations were typically similar between the two samples and exceeded Fort Devens background for 25 of 28 analyses. Only one value, lead at 26.8 μg/L in the sample from MAW-92-03X, exceeded a Maximum Contaminant Level (MCL).

4.5.2 Magazine Area Soil

Shallow soil samples were collected from three locations along the intermittent streambed within or just outside the Magazine Area and analyzed for PAL SVOCs, pesticides and PCBs, explosives, inorganics, and TOC. Review of the data shows that the pesticides DDD, DDE, and DDT were reported at concentrations up to 0.35 μg/g in the three samples. Concentrations were highest in the sample collected at MAD-92-01X. Explosives were not detected in any of the three samples. Samples from two locations (MAD-92-02X and MAD-92-03X) within the Magazine Area had reported concentrations of the SVOCs fluoranthene, phenanthrene, and pyrene of 1 μg/g or less. Eleven SVOCs were detected in the sample from MAD-93-01X at concentrations of up to 10 μg/g. MAD-93-01X is located outside the Magazine Area and may receive contamination from other sources.

Comparison of the organic data to reportable concentrations (RCs) listed in the Massachusetts Contingency Plan (MCP), shows that four compounds in sample MAD-92-01X exceeded the S1 RCs. These compounds are benzo(a)anthracene (4 versus 0.7 μg/g), benzo(a)pyrene (4 versus 0.7 μg/g), benzo(b)fluoranthene (9 versus 0.7 μg/g), and chrysene (8 versus 0.7 μg/g). No exceedances were noted for samples MAD-92-02X and MAD-92-03X.

A total of 16 inorganics were reported in the samples. Review of the data and comparison to Fort Devens soil background concentrations show that the highest observed concentrations were at MAD-92-01X, where 15 of 16 detected analytes exceeded the 68th percentile upperbound. Examples include arsenic (140 μg/g versus 21 μg/g), chromium (67.9 μg/g versus 31 μg/g), copper (50 μg/g versus 8.39 μg/g), and lead (58 μg/g versus 34.4 μg/g). Exceedances at MAD-92-02X and MAD-92-03X were fewer and less extensive. In the case of arsenic and chromium, the 68th percentile upperbound was exceeded only marginally in one of the two samples, and the average of the two samples was below this comparison concentration. In the case of copper, nickel, and sodium, one value was marginally above the comparison concentration and the second exceeded it by approximately a factor of two.

Comparison of the inorganic data to RCs shows that arsenic and cobalt at sample location MAD-92-01X exceed S1 RCs: 140 versus 30 μg/g and 20.5 versus 10 μg/g, respectively. Cobalt did not exceed the S2 RC of 100 μg/g. No exceedances were noted for samples MAD-92-02X and MAD-92-03X.

Based on the above considerations, the Magazine Area soil as represented by MAD-92-02X and MAD-92-03X is interpreted to have low level contamination with fluoranthene, phenanthrene, and pyrene that does not exceed RCs contained in the MCP. Sample location MAD-92-01X, located outside of the Magazine Area, appears contaminated with several polynuclear aromatic hydrocarbons (PAHs) and inorganics. The source of this contamination is not known; however, the low concentrations in the upstream samples indicate that the Magazine Area is not a current source. The Magazine Area does not appear to be a source of explosives contamination.

4.6 New Cranberry Pond Sediment

New Cranberry Pond was included in supplemental RI sampling activities because it was a potential biological reference pond for Group 1A sites.

Three shallow sediment samples were collected at benthic sampling locations at New Cranberry Pond and analyzed for PAL VOCs, SVOCs, pesticides and PCBs, explosives, inorganics, and TOC (see Figure 2-10). Analytical data are summarized in Table 4-29. Review of the data shows that only two VOC/SVOC

compounds were reported: toluene at 0.001 $\mu g/g$ in the sample from CRD-92-01X and phenol at 0.87 $\mu g/g$ in the sample from CRD-92-02X. Toluene was also found in five of 21 rinsate blanks at concentrations up to 4.2 $\mu g/L$; consequently, it is not considered a sediment contaminant (see Appendix H). The pesticides DDD, DDE, and DDT were reported at concentrations up to 0.6 $\mu g/g$ in the samples from CRD-92-02X and CRD-92-03X.

Review of the inorganic data shows low concentrations of 17 PAL inorganics in the three samples. In general, the sample from CRD-92-01X had the lowest concentration and CRD-92-02X had the highest. Exceedances of sediment evaluation criteria were limited to arsenic and lead. Arsenic, with a maximum concentration of 13.8 $\mu g/g$, exceeded the USEPA Region V sediment criteria in all three samples. Lead, with a maximum concentration of 97 $\mu g/g$, exceeded the USEPA Region V sediment criterion in the sample from CRD-92-02X.

Based on these three samples, the New Cranberry Pond benthic sampling locations have low level contamination by phenol, DDD, DDE, DDT, arsenic, and lead.

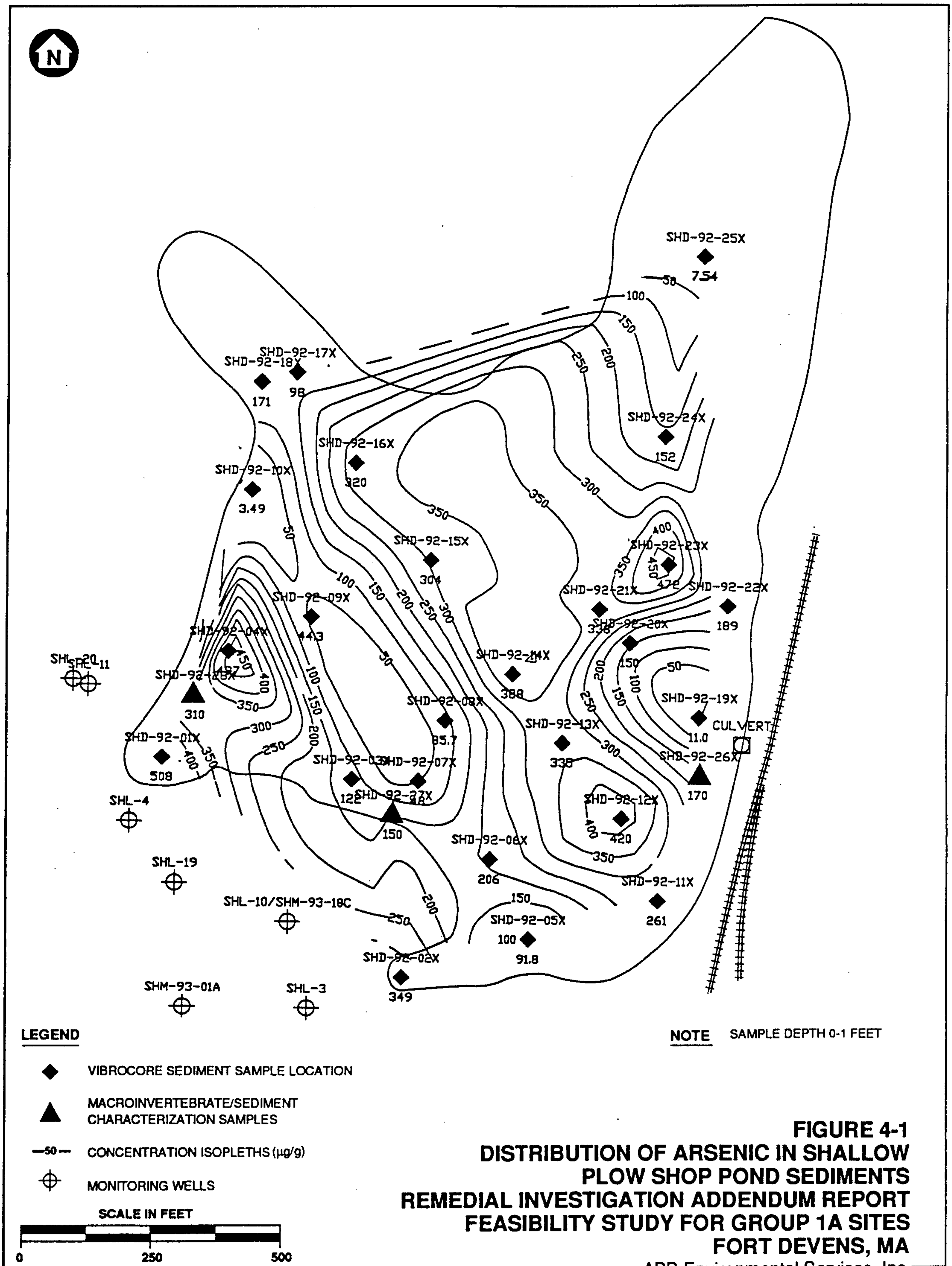

FIGURE 4-1
DISTRIBUTION OF ARSENIC IN SHALLOW PLOW SHOP POND SEDIMENTS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9307007D

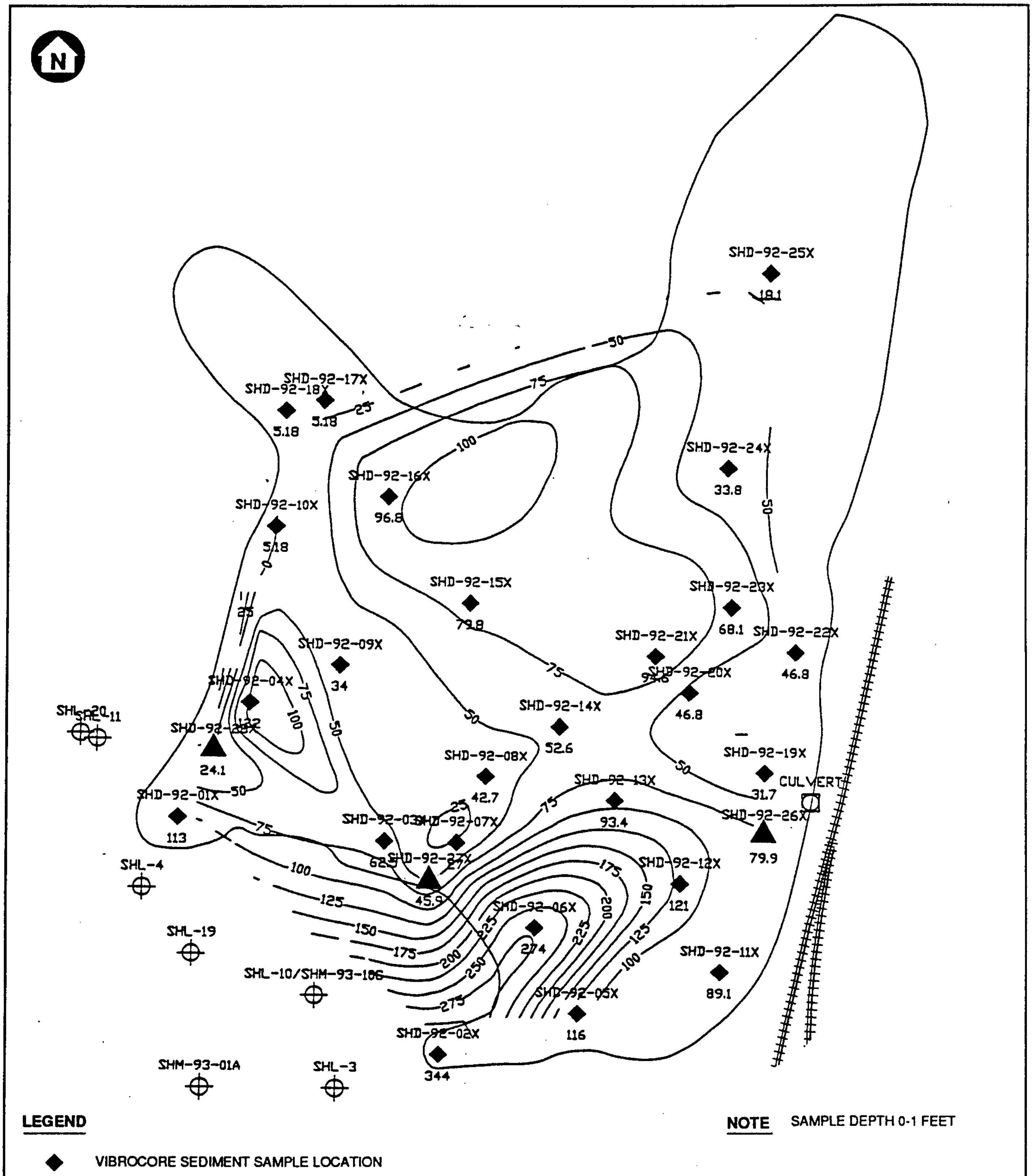

FIGURE 4-2
DISTRIBUTION OF BARIUM IN SHALLOW PLOW SHOP POND SEDIMENTS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

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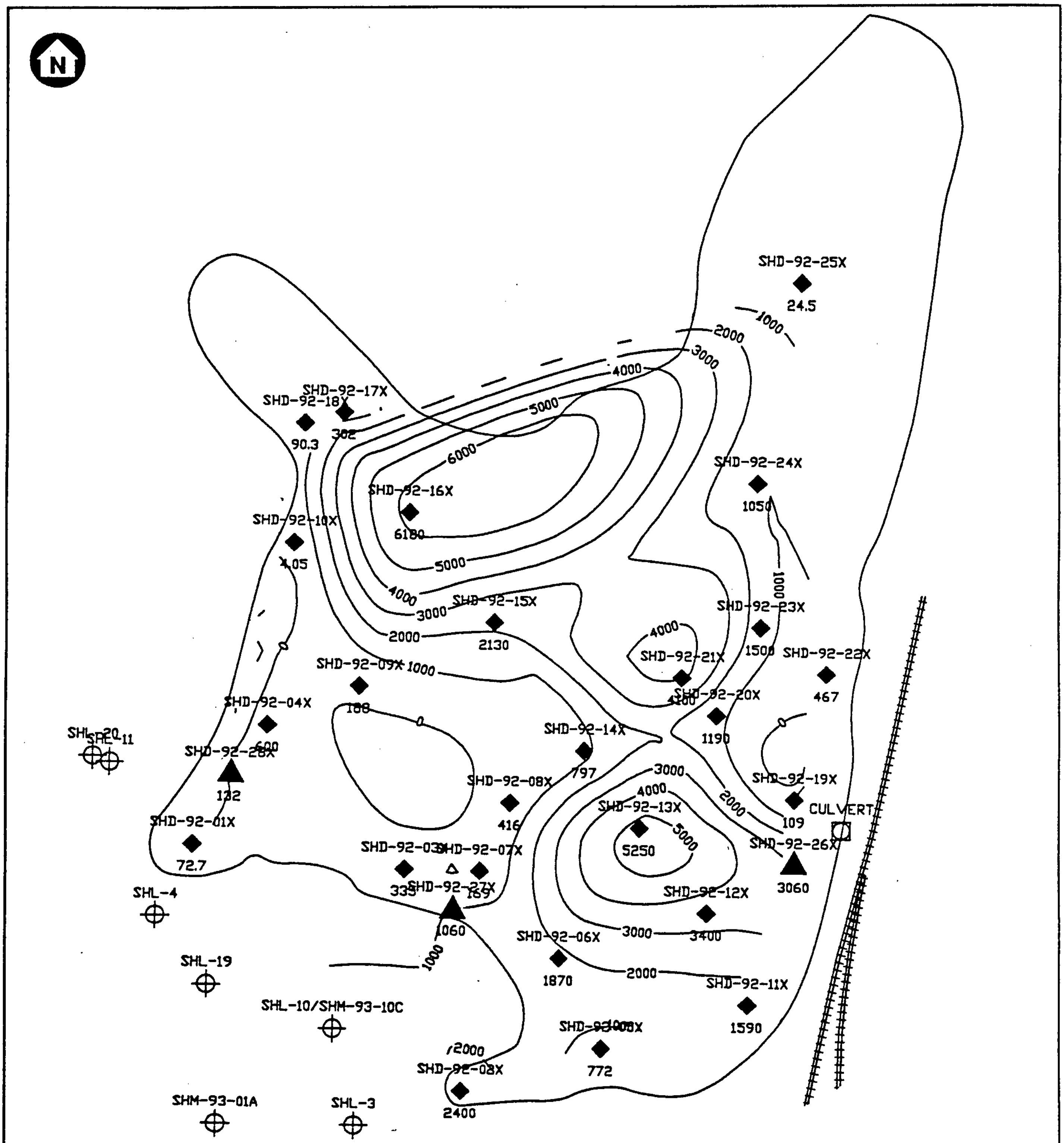

LEGEND

◆ VIBROCORE SEDIMENT SAMPLE LOCATION

▲ MACROINVERTEBRATE/SEDIMENT CHARACTERIZATION SAMPLES

—50— CONCENTRATION ISOPLETHS (µg/g)

⊕ MONITORING WELLS

SCALE IN FEET

0 250 500

NOTE SAMPLE DEPTH 0-1 FEET

FIGURE 4-3
DISTRIBUTION OF CHROMIUM IN SHALLOW PLOW SHOP POND SEDIMENTS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

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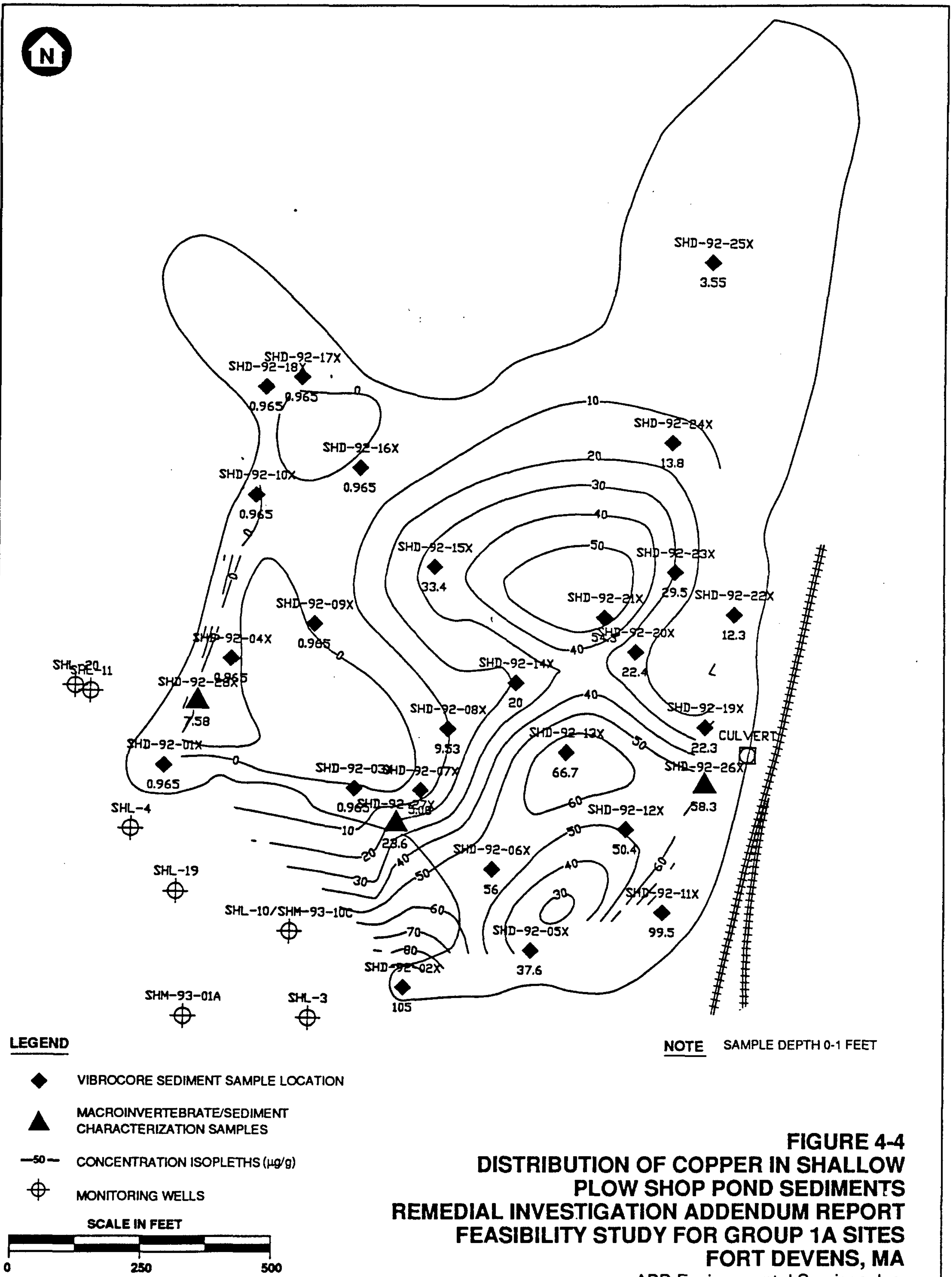

FIGURE 4-4
DISTRIBUTION OF COPPER IN SHALLOW PLOW SHOP POND SEDIMENTS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

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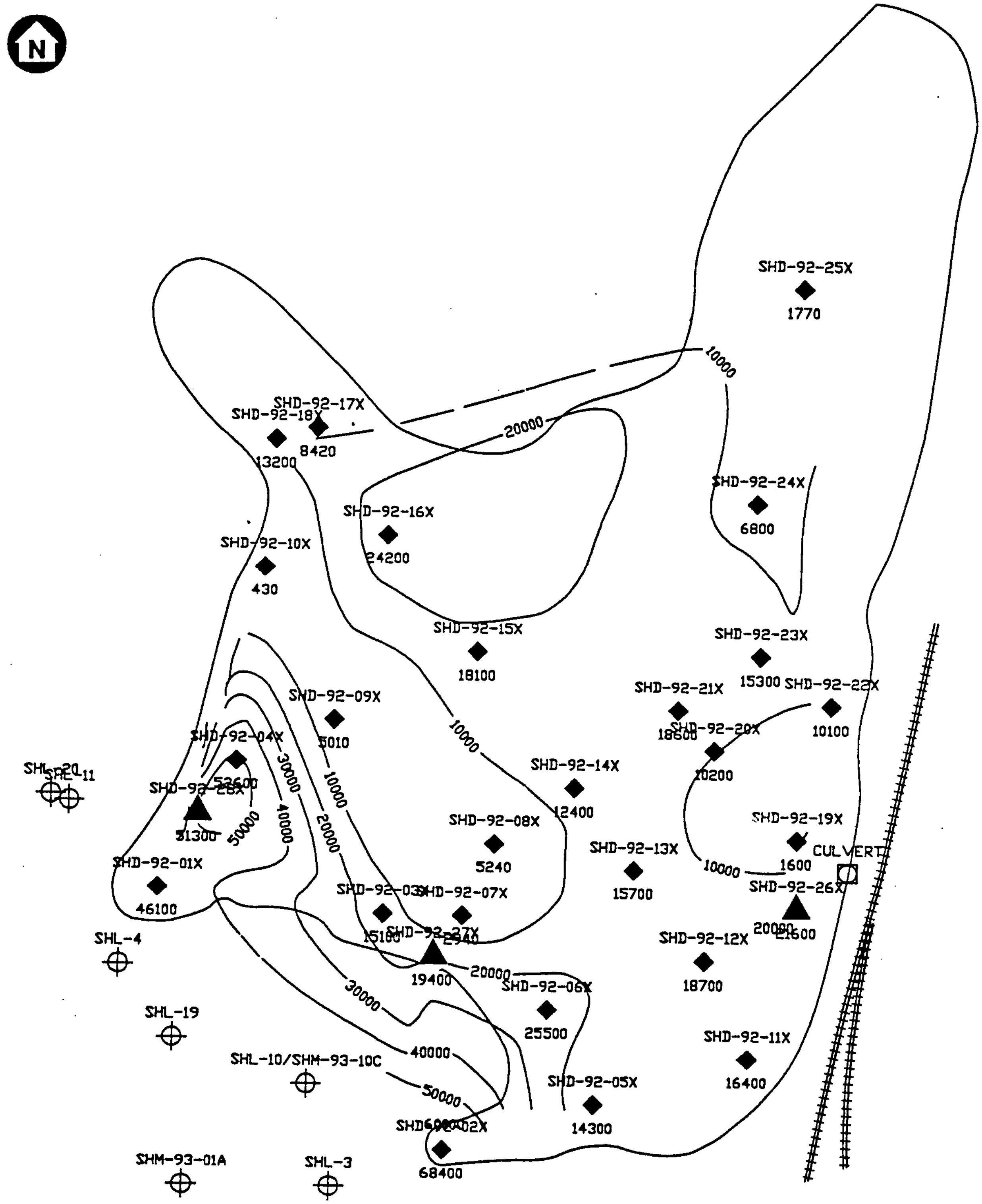

LEGEND

◆ VIBROCORE SEDIMENT SAMPLE LOCATION

▲ MACROINVERTEBRATE/SEDIMENT CHARACTERIZATION SAMPLES

—50— CONCENTRATION ISOPLETHS (µg/g)

⊕ MONITORING WELLS

SCALE IN FEET

0 250 500

NOTE SAMPLE DEPTH 0-1 FEET

FIGURE 4-5
DISTRIBUTION OF IRON IN SHALLOW PLOW SHOP POND SEDIMENTS
REMEDIAL INVESTIGATION ADDENDUM REPORT FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

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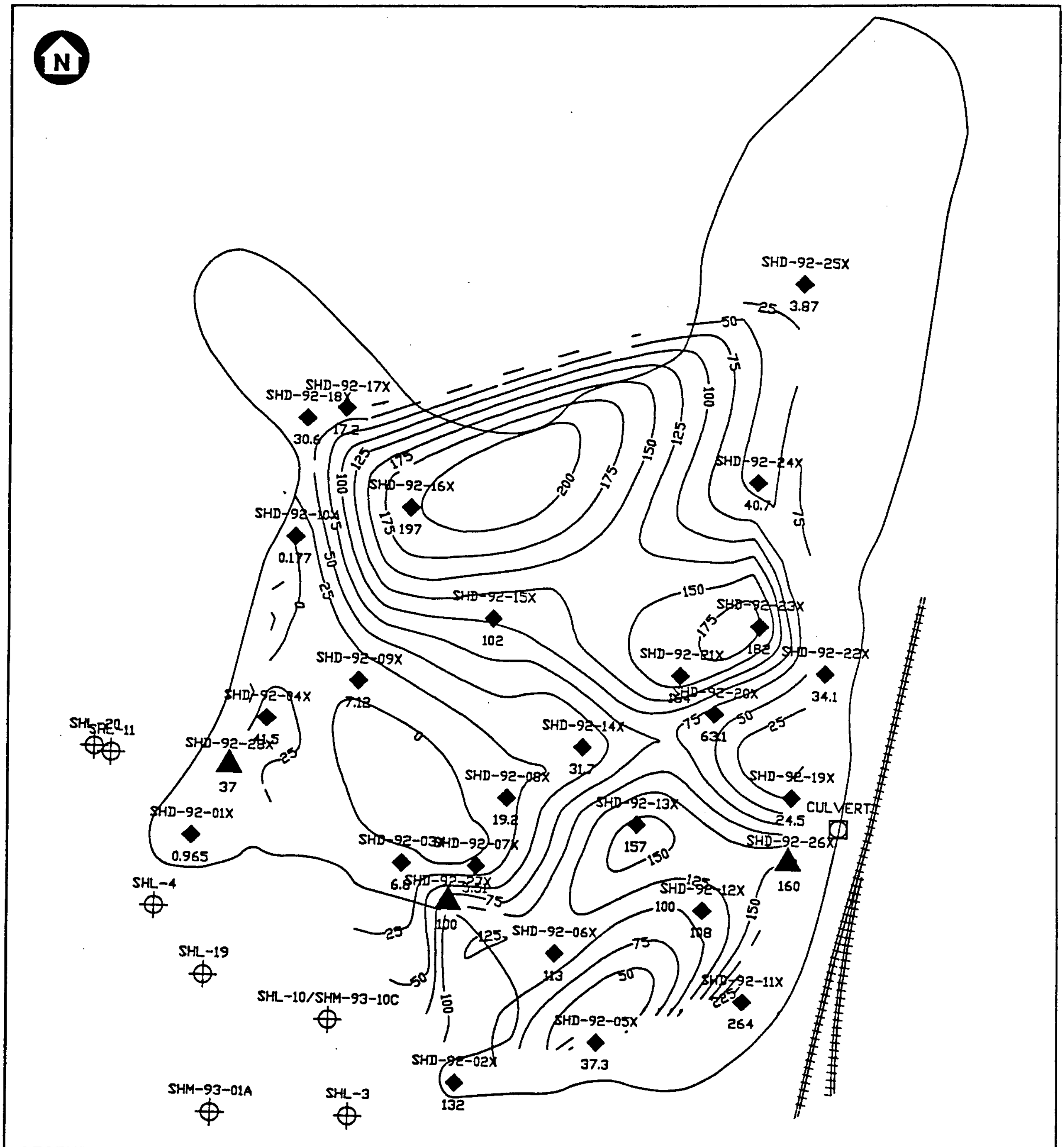

LEGEND

◆ VIBROCORE SEDIMENT SAMPLE LOCATION

▲ MACROINVERTEBRATE/SEDIMENT CHARACTERIZATION SAMPLES

—50— CONCENTRATION ISOPLETHS (µg/g)

⊕ MONITORING WELLS

SCALE IN FEET

0 250 500

NOTE SAMPLE DEPTH 0-1 FEET

FIGURE 4-6
DISTRIBUTION OF LEAD IN SHALLOW PLOW SHOP POND SEDIMENTS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

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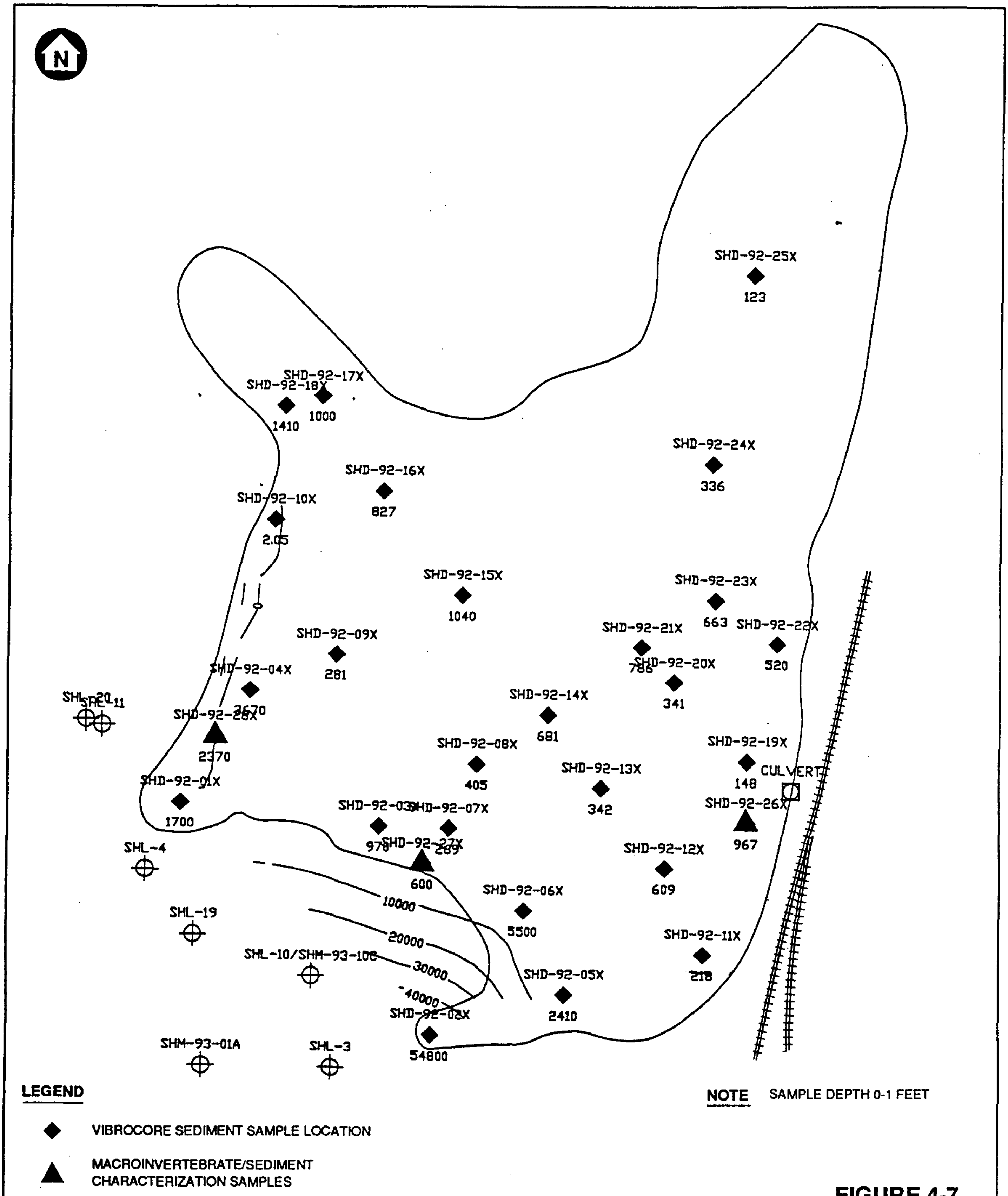

FIGURE 4-7
DISTRIBUTION OF MANGANESE IN SHALLOW PLOW SHOP POND SEDIMENTS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

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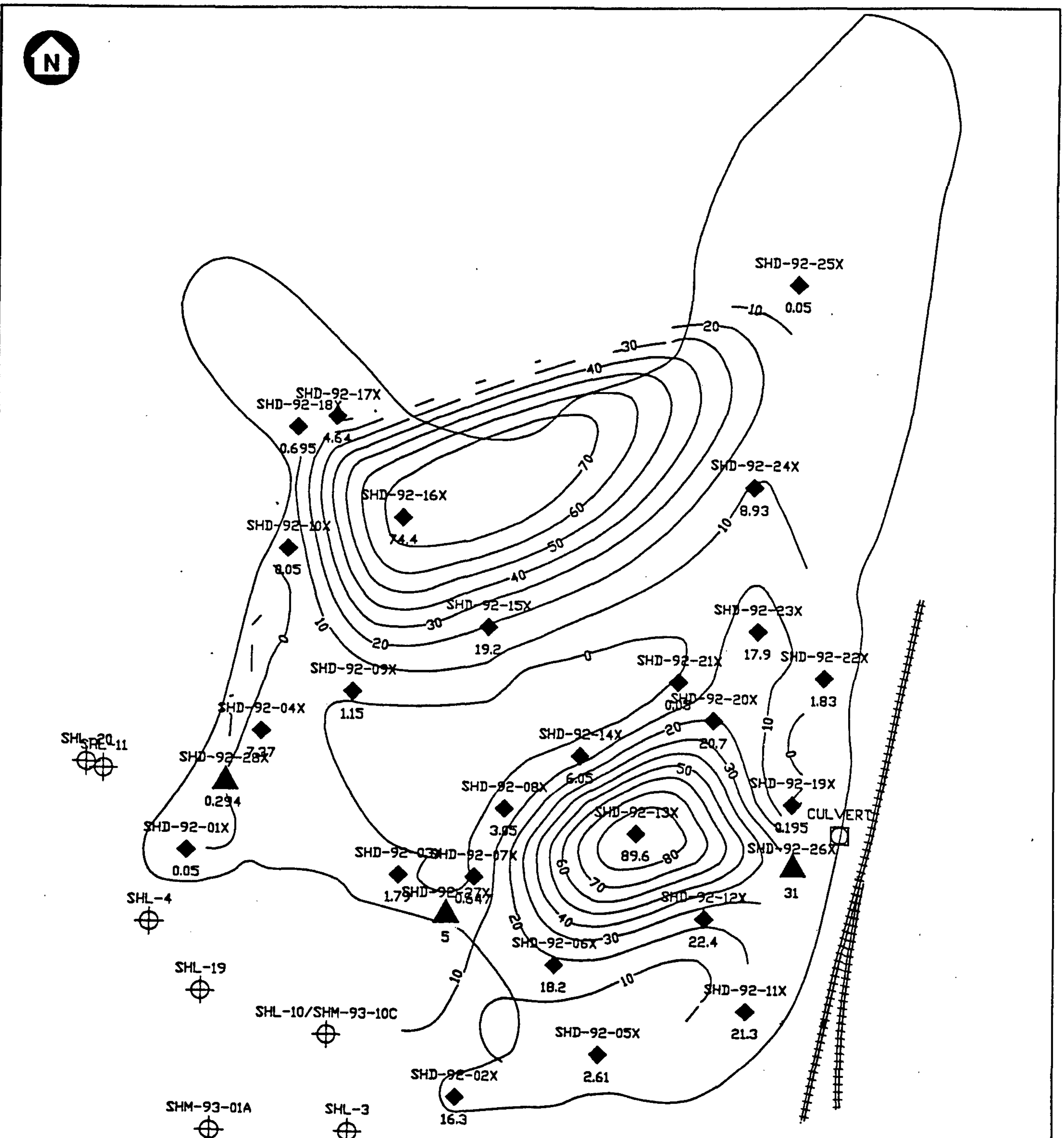

LEGEND

◆ VIBROCORE SEDIMENT SAMPLE LOCATION

▲ MACROINVERTEBRATE/SEDIMENT CHARACTERIZATION SAMPLES

—50— CONCENTRATION ISOPLETHS (µg/g)

⌖ MONITORING WELLS

SCALE IN FEET

0 250 500

NOTE SAMPLE DEPTH 0-1 FEET

FIGURE 4-8
DISTRIBUTION OF MERCURY IN SHALLOW PLOW SHOP POND SEDIMENTS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

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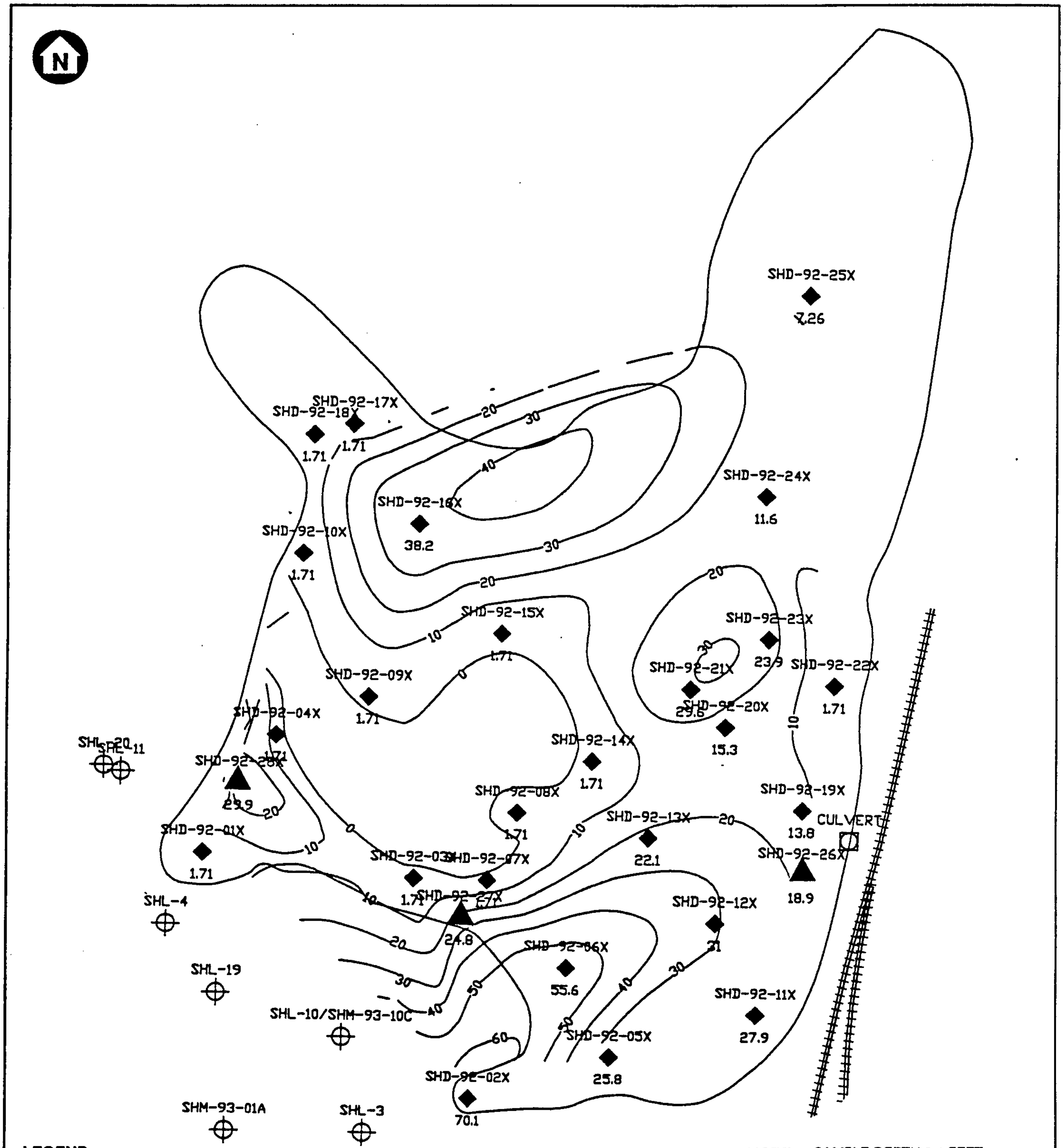

LEGEND

◆ VIBROCORE SEDIMENT SAMPLE LOCATION

▲ MACROINVERTEBRATE/SEDIMENT CHARACTERIZATION SAMPLES

—50— CONCENTRATION ISOPLETHS (µg/g)

⊕ MONITORING WELLS

SCALE IN FEET

0 250 500

NOTE SAMPLE DEPTH 0-1 FEET

FIGURE 4-9
DISTRIBUTION OF NICKEL IN SHALLOW PLOW SHOP POND SEDIMENTS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

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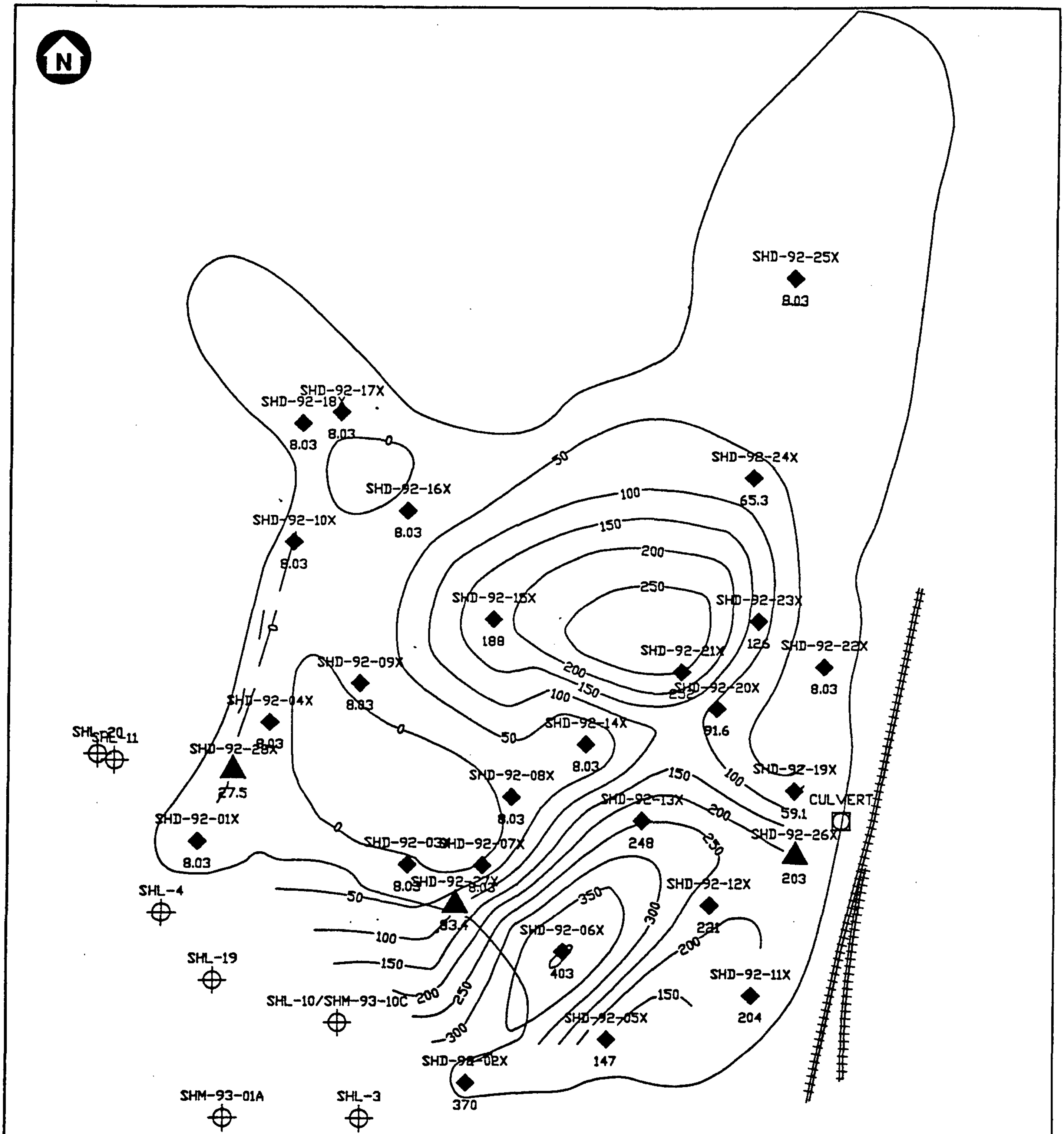

LEGEND

◆ VIBROCORE SEDIMENT SAMPLE LOCATION

▲ MACROINVERTEBRATE/SEDIMENT CHARACTERIZATION SAMPLES

—50— CONCENTRATION ISOPLETHS (μg/g)

⌖ MONITORING WELLS

SCALE IN FEET

0 250 500

NOTE SAMPLE DEPTH 0-1 FEET

FIGURE 4-10
DISTRIBUTION OF ZINC IN SHALLOW PLOW SHOP POND SEDIMENTS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

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TABLE 4-1
CALCULATED BACKGROUND CONCENTRATIONS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SOIL		GROUNDWATER	
ANALYTE	CONCENTRATION (ug/g)	ANALYTE	CONCENTRATION (ug/L)
Aluminum	15000	Aluminum	6870
Antimony	--	Antimony	3.03
Arsenic	21	Arsenic	10.5
Barium	42.5	Barium	39.6
Beryllium	0.347	Beryllium	5.00
Cadmium	2.00	Cadmium	4.01
Calcium	1400	Calcium	14700
Chromium	31	Chromium	14.7
Cobalt	--	Cobalt	25.0
Copper	8.39	Copper	8.09
Iron	15000	Iron	9100
Lead	34.4	Lead	4.25
Magnesium	5600	Magnesium	3480
Manganese	300	Manganese	291
Mercury	0.22	Mercury	0.243
Nickel	14.0	Nickel	34.3
Potassium	1700	Potassium	2370
Selenium	--	Selenium	3.02
Silver	.086	Silver	4.60
Sodium	131	Sodium	10800
Thallium	--	Thallium	6.99
Vanadium	28.7	Vanadium	11.0
Zinc	35.5	Zinc	21.1

TABLE 4-2
SEDIMENT EVALUATION CRITERIA

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	USEPA REGION V[1] (ug/g)	ONTARIO MOE (ug/g)
INORGANICS		
Arsenic	3	4.2
Barium	20	NA
Cadmium	NA	1.1
Chromium	25	31
Copper	25	25
Iron	17000	31200
Lead	40	23
Manganese	300	400
Mercury	NA	0.10
Nickel	20	31
Vanadium	NA	NA
Zinc	90	65

Notes:

[1]Concentrations above listed value are considered moderately polluted, concentrations below are considered nonpolluted

[2]NA = not applicable

MOE = Ontario Ministry of the Environment

TABLE 4-3
ROUND 1 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	SHL-3 UNFILTERED	SHL-3 FILTERED	SHL-4 UNFILTERED	SHL-4 FILTERED	SHL-5 UNFILTERED	SHL-5 FILTERED	SHL-6 UNFILTERED
VOLATILE ORGANIC COMPOUNDS (ug/L)							
1,1-dichloroethane	< 0.68		< 0.68		< 0.68		< 0.68
1,2-dichloroethylenes (cis and trans isomers)	< 0.5		< 0.5		< 0.5		< 0.5
1,2-dichloroethane	< 0.5		< 0.5		< 0.5		< 0.5
1,2-dichloropropane	< 0.5		< 0.5		< 0.5		< 0.5
benzene	< 0.5		< 0.5		< 0.5		< 0.5
chloroethane	< 1.9		< 1.9		< 1.9		< 1.9
chloroform	< 0.5		< 0.5		< 0.5		< 0.5
dichlorobenzenes	ND 10 R		ND 10 R		ND 10 R		ND 10 R
trichloroethylene / trichloroethene	< 0.5		< 0.5		< 0.5		< 0.5
trichlorofluoromeyhane	< 1.4		< 1.4		< 1.4		< 1.4
EXPLOSIVES (ug/L)							
nitroglycerine	< 10		< 10		< 10		< 10
INORGANICS (ug/L)							
aluminum	1110	< 141	3520	< 141	1060	236	2830
arsenic	6.5	< 2.54	< 2.54	14.6	11.4	9.49	9.38
barium	7	4.64	36.5	18.1	8.22	5.96	21.9
calcium	3910	3430	8900	8520	16100	15400	21500
cobalt	< 25	< 25	< 25	< 25	< 25	< 25	< 25
chromium	8.15	< 6.02	9.59	< 6.02	< 6.02	< 6.02	9.61
copper	8.37	< 8.09	8.89	< 8.09	< 8.09	< 8.09	< 8.09
iron	2160	< 38.8	11100	830	4860	3900	5050
potassium	< 375	< 375	3790	3110	3360	3420	2890
magnesium	735	< 500	4040	3350	3270	3140	3400
manganese	44.4	3	453	264	459	454	324
sodium	1100	1010	9100	8020	2180	2250	23000
nickel	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3
lead	6.83	1.52	6.51	< 1.26	3.8	< 1.26	4.34
antimony	3.3	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03
vanadium	< 11	< 11	< 11	< 11	11.5	< 11	< 11
zinc	< 21.1	< 21.1	< 21.1	< 21.1	< 21.1	< 21.1	< 21.1
OTHER (ug/L)							
alkalinity	20000		41000		53000		7500
total hardness	12000		38000		50800		60000
total organic carbon	1280		5130		17100		< 1000
total dissolved solids	31000		80000		89000		171000
total suspended solids	127000		72000		66000		241000

Notes:
< = Less than
ND = not detected
R= Analyte required for reporting purposes,
but not currently certified.
S = Results based on internal standard.

TABLE 4-3
ROUND 1 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	SHL-7 UNFILTERED	SHL-8D UNFILTERED	SHL-8S UNFILTERED	SHL-9 UNFILTERED	SHL-9 FILTERED	SHM-93-01A FILTERED	SHL-10 UNFILTERED
VOLATILE ORGANIC COMPOUNDS (ug/L)							
1,1-dichloroethane	< 0.68	< 0.68	< 0.68	< 0.68			< 0.68
1,2-dichloroethylenes (cis and trans isomers)	< 0.5	< 0.5	< 0.5	< 0.5			< 0.5
1,2-dichloroethane	< 0.5	< 0.5	< 0.5	< 0.5			< 0.5
1,2-dichloropropane	< 0.5	< 0.5	< 0.5	< 0.5			< 0.5
benzene	< 0.5	< 0.5	< 0.5	< 0.5			< 0.5
chloroethane	< 1.9	< 1.9	< 1.9	< 1.9			< 1.9
chloroform	< 0.5	< 0.5	< 0.5	< 0.5			0.87
dichlorobenzenes	ND 10 R	ND 10 R	ND 10 R	ND 10 R			ND 10 R
trichloroethylene / trichloroethene	< 0.5	< 0.5	< 0.5	< 0.5			< 0.5
trichlorofluoromeyhane	< 1.4	< 1.4	< 1.4	< 1.4			< 1.4
EXPLOSIVES (ug/L)							
nitroglycerine	< 10	< 10	< 10	< 10			< 10
INORGANICS (ug/L)							
aluminum	344	< 141	< 141	637	< 141	< 141	75500
arsenic	< 2.54	< 2.54	< 2.54	42.4	20.9	< 2.54	280
barium	12.6	9.35	5.53	20.8	18.3	8.19	350
calcium	22600	15400	7050	36600	35400	14400	18900
cobalt	< 25	< 25	< 25	< 25	< 25	< 25	54.6
chromium	6	< 6.02	< 6.02	< 6.02	< 6.02	< 6.02	115
copper	8.35	< 8.09	< 8.09	< 8.09	< 8.09	< 8.09	92.2
iron	1390	53.4	79.6	9220	6450	< 38.8	95900
potassium	3390	2080	1920	4510	4490	2940	14500
magnesium	2180	2060	993	2380	2260	1710	22300
manganese	3080	712	1590	515	485	637	2130
sodium	8280	4480	5560	2010	1990	2850	3180
nickel	< 34.3	34.3	< 34.3	< 34.3	< 34.3	< 34.3	177
lead	1.84	< 1.26	< 1.26	1.63	< 1.26	< 1.26	66.8
antimony	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03
vanadium	< 11	< 11	< 11	< 11	< 11	< 11	79.1
zinc	< 21.1	< 21.1	< 21.1	< 21.1	< 21.1	< 21.1	220
OTHER (ug/L)							
alkalinity	78000	41000	25500	102000			20000
total hardness	62400	46000	20000	92800			56800
total organic carbon	3730	1280	< 1000	13200			1280
total dissolved solids	118000	83000	57000	132000			570000
total suspended solids	53000	14000	4000	34000			3210000

Notes:

< = Less than

ND = not detected

R= Analyte required for reporting purposes, but not currently certified.

S = Results based on internal standard.

TABLE 4-3
ROUND 1 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	SHL-10 FILTERED	SHL-10 (DUP) UNFILTERED	SHL-10 (DUP) FILTERED	SHL-11 UNFILTERED	SHL-11 FILTERED	SHL-12 UNFILTERED	SHL-12 FILTERED
VOLATILE ORGANIC COMPOUNDS (ug/L)							
1,1-dichloroethane		< 0.68		< 0.68		< 0.68	
1,2-dichloroethylenes (cis and trans isomers)		< 0.5		3.4		< 0.5	
1,2-dichloroethane		< 0.5		0.51		< 0.5	
1,2-dichloropropane		< 0.5		< 0.5		< 0.5	
benzene		< 0.5		1.7		< 0.5	
chloroethane		< 1.9		< 1.9		< 1.9	
chloroform		< 0.5		0.63		< 0.5	
dichlorobenzenes		ND 10 R		ND 10 R		ND 10 R	
trichloroethylene / trichloroethene		< 0.5		< 0.5		< 0.5	
trichlorofluoromeyhane		< 1.4		< 1.4		< 1.4	
EXPLOSIVES (ug/L)							
nitroglycerine		< 10		< 10		< 10	
INORGANICS (ug/L)							
aluminum	< 141	15400	< 141	2580	< 141	5660	< 141
arsenic	< 2.54	58.6	< 2.54	340	230	31.6	< 2.54
barium	5.32	78.1	5.14	122	117	33.1	8.98
calcium	8620	13000	8220	56800	57400	14300	11400
cobalt	< 25	< 25	< 25	< 25	< 25	< 25	< 25
chromium	< 6.02	28	< 6.02	< 6.02	< 6.02	14.5	< 6.02
copper	< 8.09	15	< 8.09	9.2	< 8.09	11	< 8.09
iron	< 38.8	18300	43.9	97400	91600	10500	< 38.8
potassium	968	4860	1750	10700	10600	2880	540
magnesium	871	5110	895	8970	8420	3140	908
manganese	11.2	463	10.5	4890	4800	336	14.8
sodium	1420	2250	1340	52300	53800	6520	5890
nickel	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3
lead	1.41	14.9	< 1.26	1.63	< 1.26	8.46	< 1.26
antimony	< 3.03	< 3.03	< 3.03	2.77	< 3.03	< 3.03	< 3.03
vanadium	< 11	21.9	< 11	< 11	< 11	< 11	< 11
zinc	< 21.1	50.8	< 21.1	< 21.1	< 21.1	30	< 21.1
OTHER (ug/L)							
alkalinity		23000		255000		36000	
total hardness		39600		164000		40000	
total organic carbon		< 1000		12900		1580	
total dissolved solids		48000		458000		66000	
total suspended solids		1680000		204000		240000	

Notes:
< = Less than
ND = not detected
R = Analyte required for reporting purposes,
but not currently certified.
S = Results based on internal standard.

TABLE 4-3
ROUND 1 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	SHL-13 UNFILTERED	SHL-13 FILTERED	SHL-15 UNFILTERED	SHL-15 FILTERED	SHL-17 UNFILTERED	SHL-18 UNFILTERED	SHL-19 UNFILTERED
VOLATILE ORGANIC COMPOUNDS (ug/L)							
1,1-dichloroethane	< 0.68		< 0.68		< 0.68	< 0.68	< 0.68
1,2-dichloroethylenes (cis and trans isomers)	< 0.5		< 0.5		< 0.5	< 0.5	1.6
1,2-dichloroethane	< 0.5		< 0.5		< 0.5	< 0.5	0.55
1,2-dichloropropane	< 0.5		< 0.5		< 0.5	< 0.5	< 0.5
benzene	< 0.5		< 0.5		< 0.5	< 0.5	< 0.5
chloroethane	< 1.9		< 1.9		< 1.9	< 1.9	< 1.9
chloroform	< 0.5		< 0.5		< 0.5	0.68	< 0.5
dichlorobenzenes	ND 10 R		ND 10 R		ND 10 R	ND 10 R	ND 10 R
trichloroethylene / trichloroethene	< 0.5		< 0.5		< 0.5	< 0.5	< 0.5
trichlorofluoromeyhane	< 1.4		2.1 S		< 1.4	< 1.4	< 1.4
EXPLOSIVES (ug/L)							
nitroglycerine	< 10		< 10		< 10	< 10	< 10
INORGANICS (ug/L)							
aluminum	4030	< 141	1330	< 141	352	222	1100
arsenic	17	< 2.54	24	< 2.54	3.2	3.09	390
barium	28	8.71	39.4	26.2	12.3	< 5	29.3
calcium	12000	11000	15600	16900	18800	5910	25100
cobalt	< 25	< 25	< 25	< 25	< 25	< 25	< 25
chromium	7.05	< 6.02	< 6.02	6.95	< 6.02	< 6.02	< 6.02
copper	< 8.09	< 8.09	< 8.09	< 8.09	< 8.09	< 8.09	< 8.09
iron	5350	< 38.8	1840	42.5	482	417	29600
potassium	1900	829	3260	1870	694	1920	4720
magnesium	2850	1840	1900	1860	966	783	3460
manganese	274	114	1430	1850	17.2	20.9	1890
sodium	17300	16400	7370	7630	4590	2770	5350
nickel	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3
lead	7.38	< 1.26	3.69	1.63	< 1.26	1.95	2.82
antimony	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03
vanadium	< 11	< 11	< 11	< 11	< 11	< 11	< 11
zinc	< 21.1	< 21.1	35.8	28.8	< 21.1	< 21.1	< 21.1
OTHER (ug/L)							
alkalinity	26000		15000		50000	12000	46000
total hardness	36800		47000		48600	15800	69200
total organic carbon	1530		2550		1180	< 1000	1780
total dissolved solids	109000		115000		93000	54000	114000
total suspended solids	126000		66000		29000	47000	129000

Notes:
< = Less than
ND = not detected
R= Analyte required for reporting purposes, but not currently certified.
S = Results based on internal standard.

TABLE 4-3
ROUND 1 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	SHL-19 FILTERED	SHL-20 UNFILTERED	SHL-20 FILTERED	SHL-21 UNFILTERED	SHL-22 UNFILTERED	SHL-23 UNFILTERED	SHL-23 FILTERED
VOLATILE ORGANIC COMPOUNDS (ug/L)							
1,1-dichloroethane		0.95		< 0.68	2.3	< 0.68	
1,2-dichloroethylenes (cis and trans isomers)		4		< 0.5	4.1	< 0.5	
1,2-dichloroethane		0.66		< 0.5	< 0.5	< 0.5	
1,2-dichloropropane		< 0.5		< 0.5	0.52	< 0.5	
benzene		1.6		< 0.5	1.1	< 0.5	
chloroethane		5.5		< 1.9	< 1.9	< 1.9	
chloroform		< 0.5		< 0.5	< 0.5	0.85	
dichlorobenzenes		11 S		ND 10 R	ND 10 R	ND 10 R	
trichloroethylene / trichloroethene		< 0.5		< 0.5	< 0.5	< 0.5	
trichlorofluoromeyhane		< 1.4		< 1.4	< 1.4	< 1.4	
EXPLOSIVES (ug/L)							
nitroglycerine		< 10		< 10	< 10	< 10	
INORGANICS (ug/L)							
aluminum	< 141	< 141	< 141	2850	< 141	1410	< 141
arsenic	160	330	270	14	32.9	3.3	< 2.54
barium	19.9	93.5	88.7	15	41	21.9	16.9
calcium	25100	174000	175000	9630	219000	9990	9770
cobalt	< 25	< 25	< 25	< 25	< 25	< 25	< 25
chromium	< 6.02	< 6.02	< 6.02	7.38	< 6.02	< 6.02	< 6.02
copper	< 8.09	< 8.09	< 8.09	< 8.09	< 8.09	< 8.09	< 8.09
iron	22600	20100	18800	4410	9540	1550	94.3
potassium	3840	8090	7680	1870	8660	3550	3510
magnesium	3110	20300	19900	1780	24000	1230	983
manganese	1890	9650	9540	144	8180	101	66.4
sodium	5170	67300	64600	3140	64200	1830	1810
nickel	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3
lead	< 1.26	< 1.26	< 1.26	4.88	< 1.26	< 1.26	< 1.26
antimony	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	
vanadium	< 11	< 11	< 11	< 11	< 11	< 11	< 11
zinc	< 21.1	< 21.1	< 21.1	< 21.1	122	57.7	66.2
OTHER (ug/L)							
alkalinity		600000		24000	570000	5500	
total hardness		527000		26200	17600	25600	
total organic carbon		12300		2780	22400	1370	
total dissolved solids		772000		73000	586000	76000	
total suspended solids		48000		112000	25000	47000	

Notes:
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but not currently certified.
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TABLE 4-3
ROUND 1 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	SHL-24 UNFILTERED	SHL-25 UNFILTERED	SHM-93-01A UNFILTERED	SHM-93-10C UNFILTERED	SHM-93-18B UNFILTERED	SHM-93-18B FILTERED
VOLATILE ORGANIC COMPOUNDS (ug/L)						
1,1-dichloroethane	< 0.68	< 0.68	< 0.68	4.4	< 0.68	
1,2-dichloroethylenes (cis and trans isomers)	< 0.5	< 0.5	< 0.5	7	< 0.5	
1,2-dichloroethane	< 0.5	< 0.5	< 0.5	9.9	< 0.5	
1,2-dichloropropane	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	
benzene	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	
chloroethane	< 1.9	< 1.9	< 1.9	< 1.9	< 1.9	
chloroform	0.52	< 0.5	< 0.5	< 0.5	< 0.5	
dichlorobenzenes	ND 10 R	ND 10 R	ND 10 R	ND 10 R	ND 10 R	
trichloroethylene / trichloroethene	< 0.5	0.57	< 0.5	< 0.5	< 0.5	
trichlorofluoromeyhane	< 1.4	< 1.4	< 1.4	< 1.4	< 1.4	
EXPLOSIVES (ug/L)						
nitroglycerine	< 10	< 10	< 10	< 10	< 10	
INORGANICS (ug/L)						
aluminum	195	742	2260	494	462	< 141
arsenic	20.4	3.09	7.36	21.3	< 2.54	< 2.54
barium	6.66	5.52	22.1	9.91	16.3	13.4
calcium	25400	11900	18800	73300	32900	33300
cobalt	< 25	< 25	< 25	< 25	< 25	< 25
chromium	< 6.02	< 6.02	< 6.02	< 6.02	< 6.02	< 6.02
copper	< 8.09	< 8.09	< 8.09	< 8.09	< 8.09	< 8.09
iron	323	807	3320	793	805	< 38.8
potassium	3850	2670	5220	7820	3580	3860
magnesium	3870	934	2800	3830	4140	3960
manganese	21.6	16.1	1030	64.7	254	258
sodium	6480	10300	3690	7030	27100	27100
nickel	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3
lead	5.53	2.93	4.01	< 1.26	1.95	< 1.26
antimony	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03
vanadium	< 11	< 11	< 11	< 11	< 11	< 11
zinc	36.8	< 21.1	66.5	< 21.1	< 21.1	25.5
OTHER (ug/L)						
alkalinity	44500	22500	43500	149000	76500	
total hardness	76800	32400	55200	200000	108000	
total organic carbon	< 1000	1880	2380	1520	< 1000	
total dissolved solids	124000	64000	111000	280000	205000	
total suspended solids	12000	34000	107000	710000	63000	

Notes:
< = Less than
ND = not detected
R= Analyte required for reporting purposes,
but not currently certified.
S = Results based on internal standard.

TABLE 4-3
ROUND 1 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE		SHM-93-22C UNFILTERED		SHM-93-24A UNFILTERED		SHM-93-24A FILTERED
VOLATILE ORGANIC COMPOUNDS (ug/L)						
1,1-dichloroethane		1.3	<	0.68		
1,2-dichloroethylenes (cis and trans isomers)		1.4	<	0.5		
1,2-dichloroethane	<	0.5	<	0.5		
1,2-dichloropropane	<	0.5	<	0.5		
benzene	<	0.5	<	0.5		
chloroethane	<	1.9	<	1.9		
chloroform	<	0.5	<	0.5		
dichlorobenzenes	ND	10 R	ND	10 R		
trichloroethylene / trichloroethene	<	0.5	<	0.5		
trichlorofluoromeyhane	<	1.4	<	1.4		
EXPLOSIVES (ug/L)						
nitroglycerine	<	10		80.8		
INORGANICS (ug/L)						
aluminum		310		558	<	141
arsenic		68.9		5.54	<	2.54
barium		38.5		7.61	<	5
calcium		67600		10500		10000
cobalt	<	25	<	25	<	25
chromium		9.07	<	6.02	<	6.02
copper	<	8.09	<	8.09	<	8.09
iron		203		1040	<	38.8
potassium		31800		1540		1030
magnesium		14200		1060		927
manganese		160		70.2		6.68
sodium		39600		16500		15300
nickel	<	34.3	<	34.3	<	34.3
lead	<	1.26		1.63	<	1.26
antimony	<	3.03	<	3.03	<	3.03
vanadium		12.6	<	11	<	11
zinc	<	21.1	<	21.1		30.1
OTHER (ug/L)						
alkalinity		226000		15000		
total hardness		220000		30800		
total organic carbon		4050		1120		
total dissolved solids		354000		75000		
total suspended solids		28000		36000		

Notes:
< = Less than
ND = not detected
R = Analyte required for reporting purposes, but not currently certified.
S = Results based on internal standard.

TABLE 4-4
ROUND 2 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	SHM-93-01A UNFILTERED	SHM-93-01A FILTERED	SHM-93-10C UNFILTERED	SHM-93-18B UNFILTERED	SHM-93-18B FILTERED	SHM-93-22C UNFILTERED	SHM-93-24A UNFILTERED	SHM-93-24A UNFILTERED (DUP)	SHM-93-24A FILTERED	SHM-93-24A FILTERED (DUP)
ORGANICS (ug/L)										
1,1-dichloroethane	< 0.68		3.3	< 0.68		1.8	< 0.68	< 0.68		
1,2-dichloroethane	0.84		8.1	< 0.5		< 0.5	< 0.5	< 0.5		
acetone	14 (1)		15	< 13		< 13	< 13	< 13		
toluene	< 0.5		< 0.5	< 0.5		0.56	< 0.5	< 0.5		
INORGANICS (ug/L)										
aluminum	3370	< 141	233	185	< 141	293	3430	3950	< 141	< 141
arsenic	8.32	< 2.54	18.1	< 2.54	< 2.54	49.8	22.4	20.1	< 2.54	< 2.54
barium	22	5.19	8.64	17.7	17.5	48.1	19.4	21.6	7.44	5.02
calcium	10600	9700	78600	33600	33300	79900	10800	10800	10000	10200
chromium	6.34	< 6.02	< 6.02	< 6.02	< 6.02	< 6.02	6.64	8.28	< 6.02	< 6.02
copper	< 8.09	< 8.09	< 8.09	< 8.09	< 8.09	< 8.09	11.5	10.2	< 8.09	< 8.09
iron	4180	< 38.8	260	283	< 38.8	199	6700	7140	< 38.8	< 38.8
potassium	3600	2090	8400	3800	4280	23500	1600	1870	953	923
magnesium	2210	1160	4260	4180	4130	14700	1830	1940	836	854
manganese	297	162	61.8	290	287	292	363	367	7.64	5.89
sodium	2310	1790	10900	30900	30500	41400	16800	16500	16200	16500
lead	2.82	< 1.26	< 1.26	< 1.26	< 1.26	< 1.26	5.31	5.53	< 1.26	< 1.26
antimony	< 3.03	< 3.03	< 3.03	< 3.03	3.12	< 3.03	< 3.03	< 3.03	< 3.03	< 3.03
OTHER (ug/L)										
alkalinity	23000		155000	75000		240000	14000	14000		
total hardness	30000		192000	97600		240000	28400	30800		
total organic carbon	1320		2270	1830		4800	1310	< 1000		
total dissolved solids	56000		268000	213000		381000	90000	93000		
total suspended solids	396000		7000	< 4000		16000	98000	151000		

Notes:
< = Less than
(1) = Results less than CRL, but greater than COD
DUP = duplicate sample

TABLE 4-5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD-92-01X	SHD-92-01X	SHD-92-01X	SHD-92-02X	SHD-92-02X
	0 FT	3 FT	5 FT	0 FT	3 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	1.8	< 0.008
DDE	< 0.008	< 0.008	< 0.008	1.3	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.071	< 0.007
INORGANICS (ug/g)					
aluminum	4590	7350	2930	8470	2390
arsenic	510	130	11.8	340	1.67
barium	113	63.5	13.5	344	155
beryllium	< 0.5	3.16	< 0.5	< 0.5	< 0.5
calcium	20100	10800	383	13300	9820
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	< 1.42	< 1.42	58.7	< 1.42
chromium	72.8	< 4.05	7.77	2400	< 4.05
copper	< 0.965	7.88	2.91	105	10.2
iron	46100	11600	3480	68400	1590
mercury	< 0.05	< 0.05	< 0.05	16	< 0.05
potassium	< 100	< 100	261	< 100	< 100
magnesium	1800	819	959	1700	896
manganese	1690	812	50.1	54800	154
sodium	1790	713	173	2240	821
nickel	< 1.71	10.2	9.89	70.1	< 1.71
lead	8.63	5.24	2.11	132	1.14
selenium	3.54	1.86	< 0.25	< 0.25	< 0.25
vanadium	< 3.39	< 3.39	< 3.39	61.7	< 3.39
zinc	< 8.03	< 8.03	< 8.03	370	< 8.03
OTHER (ug/g)					
total organic carbon	663000	319000	1290	825000	409000
SOLIDS (% WET WT)	10.7	32.6	76.8	6.9	24.7

Notes:
< = less than

TABLE 4-5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD-92-02X	SHD-92-03X	SHD-92-03X	SHD-92-03X	SHD-92-04X
	5 FT	0 FT	3 FT	3 FT (DUP)	0 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	11400	1900	2830	4820	2970
arsenic	2.53	120	46.1	28.5	500
barium	95.9	62.5	62.1	37.5	122
beryllium	< 0.5	< 0.5	< 0.5	5.41	< 0.5
calcium	1260	5860	15500	11000	13200
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	< 1.42	< 1.42	< 1.42	< 1.42
chromium	13.6	335	381	532	600
copper	31.8	< 0.965	< 0.965	14.5	< 0.965
iron	1090	15100	9180	10500	52600
mercury	< 0.05	1.79	1.48	2.48	7.37
potassium	< 100	< 100	< 100	< 100	< 100
magnesium	< 100	< 100	1140	945	< 100
manganese	32.2	973	787	704	3670
sodium	369	786	991	1090	1640
nickel	8.79	< 1.71	< 1.71	< 1.71	< 1.71
lead	11.2	6.82	15.1	11.6	41.5
selenium	0.896	< 0.25	2.95	2.75	< 0.25
vanadium	11.9	< 3.39	< 3.39	< 3.39	< 3.39
zinc	< 8.03	< 8.03	< 8.03	< 8.03	< 8.03
OTHER (ug/g)					
total organic carbon	152000	318000	458000	357000	568000
SOLIDS (% WET WT)	40.4	19.1	16.4	18.8	10

Notes:
< = less than

TABLE 4-5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD-92-04X	SHD-92-05X	SHD-92-05X	SHD-92-05X	SHD-92-06X
	1 FT	0 FT	2 FT	4 FT	0 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	1700	6310	1270	640	6520
arsenic	210	91.8	2.25	1.77	210
barium	99.7	116	31.5	20.9	274
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	14700	17700	10600	7110	11700
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	19.2
cobalt	< 1.42	< 1.42	< 1.42	< 1.42	22.4
chromium	475	773	< 4.05	16.7	1870
copper	< 0.965	37.6	< 0.965	< 0.965	56
iron	19600	14400	1010	1250	25500
mercury	2.45	2.61	< 0.05	< 0.05	18
potassium	< 100	< 100	< 100	< 100	< 100
magnesium	950	1380	< 100	< 100	1470
manganese	2250	2410	32.2	86.4	5500
sodium	1040	1940	911	550	2030
nickel	< 1.71	25.8	< 1.71	< 1.71	55.6
lead	9.47	37.3	< 0.177	3.28	113
selenium	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
vanadium	< 3.39	< 3.39	< 3.39	< 3.39	< 3.39
zinc	< 8.03	147	< 8.03	41.8	403
OTHER (ug/g)					
total organic carbon	490000	840000	400000	228000	499000
SOLIDS (% WET WT)	17.8	7.8	19.2	33.1	7.4

Notes:
< = less than

TABLE 4-5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD-92-06X	SHD-92-06X	SHD-92-07X	SHD-92-07X	SHD-92-08X
	3 FT	5 FT	0 FT	3 FT	0 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	899	1230	1290	1190	1590
arsenic	3.73	14.3	48	25.7	86
barium	22.6	30.4	27	34.3	42.7
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	12000	11100	5850	10900	12200
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	< 1.42	< 1.42	< 1.42	< 1.42
chromium	< 4.05	97.9	169	203	416
copper	< 0.965	5.22	5.08	< 0.965	9.53
iron	833	2420	2940	2390	5240
mercury	< 0.05	0.325	0.646	1.49	3.05
potassium	< 100	< 100	< 100	< 100	< 100
magnesium	591	694	471	713	727
manganese	46	354	270	235	405
sodium	725	797	646	972	1000
nickel	< 1.71	< 1.71	< 1.71	< 1.71	< 1.71
lead	0.956	4.46	5.51	8.58	19.3
selenium	< 0.25	< 0.25	< 0.25	1.94	< 0.25
vanadium	< 3.39	< 3.39	< 3.39	< 3.39	< 3.39
zinc	< 8.03	< 8.03	< 8.03	< 8.03	< 8.03
OTHER (ug/g)					
total organic carbon	298000	375000	315000	348000	453000
SOLIDS (% WET WT)	26.1	20.4	25.5	18.2	16.1

Notes:
< = less than

TABLE 4–5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD–92–08X	SHD–92–08X	SHD–92–09X	SHD–92–09X	SHD–92–09X
	4 FT	7 FT	0 FT	3 FT	5 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	1260	816	859	353	638
arsenic	2.91	13.6	44.3	2.71	4.43
barium	17.4	30.2	34	15.3	26
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	7450	6860	7940	5980	9380
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	< 1.42	< 1.42	< 1.42	< 1.42
chromium	25.5	168	188	< 4.05	< 4.05
copper	3.56	4.03	< 0.965	< 0.965	< 0.965
iron	946	2940	5010	335	1140
mercury	< 0.05	2.69	1.15	< 0.05	< 0.05
potassium	< 100	< 100	< 100	< 100	< 100
magnesium	< 100	< 100	551	447	431
manganese	68.1	255	281	16.9	61.9
sodium	587	575	924	516	696
nickel	< 1.71	< 1.71	< 1.71	< 1.71	< 1.71
lead	1.45	6.97	7.13	< 0.177	0.827
selenium	1.33	1.27	< 0.25	< 0.25	1.53
vanadium	< 3.39	< 3.39	< 3.39	< 3.39	< 3.39
zinc	< 8.03	< 8.03	< 8.03	< 8.03	< 8.03
OTHER (ug/g)					
total organic carbon	208000	248000	310000	227000	377000
SOLIDS (% WET WT)	31.7	29	19.7	40.9	28.4

Notes:
< = less than

TABLE 4–5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD–92–10X	SHD–92–10X	SHD–92–10X	SHD–92–11X	SHD–92–12X
	0 FT	3 FT	5 FT	0 FT	0 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	0.074	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	388	775	767	8150	9250
arsenic	3.49	13.1	93	260	420
barium	< 5.18	26.4	39.3	89.1	121
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	6850	10600	8650	8210	8410
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	< 1.42	< 1.42	< 1.42	< 1.42
chromium	< 4.05	35.4	139	1590	3400
copper	< 0.965	< 0.965	< 0.965	99.5	50.4
iron	428	1650	13500	16400	18600
mercury	< 0.05	0.719	1.14	22	22
potassium	< 100	< 100	< 100	< 100	< 100
magnesium	< 100	501	< 100	2060	1800
manganese	< 2.05	36.1	506	218	608
sodium	574	871	885	1600	2000
nickel	< 1.71	< 1.71	< 1.71	27.9	31
lead	< 0.177	1.99	3.96	260	108
selenium	< 0.25	< 0.25	< 0.25	5.85	< 0.25
vanadium	< 3.39	< 3.39	< 3.39	< 3.39	< 3.39
zinc	< 8.03	< 8.03	< 8.03	204	221
OTHER (ug/g)					
total organic carbon	232000	327000	293000	536000	513000
SOLIDS (% WET WT)	30.1	22.1	20	10.7	7.7

Notes:
< = less than

TABLE 4-5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD-92-12X 3 FT	SHD-92-12X 4 FT	SHD-92-13X 0 FT	SHD-92-13X 3 FT	SHD-92-13X 5 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	5100	1830	7360	6930	6890
arsenic	4.42	1.53	340	29.6	12.7
barium	44.6	16.5	93.4	60.3	77.7
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	2690	846	3290	7310	8000
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	4.54	< 1.42	10.2	< 1.42	< 1.42
chromium	23.6	< 4.05	5250	184	71.9
copper	3.32	< 0.965	66.7	9.95	6.04
iron	4120	1860	15700	3760	5860
mercury	< 0.05	< 0.05	89	1.33	0.478
potassium	< 100	< 100	817	< 100	< 100
magnesium	1290	607	1630	782	1450
manganese	141	53.2	342	270	546
sodium	556	248	792	962	768
nickel	10.2	4	22.1	< 1.71	17
lead	3.58	0.757	160	13.9	7.76
selenium	1.22	< 0.25	2.77	< 0.25	1.72
vanadium	< 3.39	< 3.39	21.6	< 3.39	< 3.39
zinc	< 8.03	< 8.03	248	< 8.03	< 8.03
OTHER (ug/g)					
total organic carbon	170000	32800	801000	612000	650000
SOLIDS (% WET WT)	35.5	69.2	19.1	17	19.7

Notes:
< = less than

TABLE 4-5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD-92-14X	SHD-92-14X	SHD-92-14X	SHD-92-15X	SHD-92-15X
	0 FT	3 FT	5 FT	0 FT	3 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	4280	2680	4080	5460	1220
arsenic	390	28.8	8.44	300	12.6
barium	52.6	< 5.18	< 5.18	79.8	< 5.18
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	11100	16400	12500	16200	23000
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	< 1.42	< 1.42	< 1.42	< 1.42
chromium	797	< 4.05	< 4.05	2130	< 4.05
copper	20	< 0.965	10.5	33.4	< 0.965
iron	12300	2440	2380	18100	1690
mercury	6.05	< 0.05	< 0.05	19	< 0.05
potassium	< 100	< 100	< 100	< 100	< 100
magnesium	< 100	< 100	< 100	1540	1730
manganese	681	184	288	1040	178
sodium	1770	2580	1740	2870	2340
nickel	< 1.71	< 1.71	< 1.71	< 1.71	< 1.71
lead	31.7	5.06	4.14	102	3.56
selenium	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
vanadium	< 3.39	< 3.39	< 3.39	< 3.39	< 3.39
zinc	< 8.03	< 8.03	< 8.03	188	< 8.03
OTHER (ug/g)					
total organic carbon	671000	898000	1040000	575000	674000
SOLIDS (% WET WT)	10.7	9.5	11.4	8.1	9.9

Notes:
< = less than

TABLE 4-5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD-92-15X	SHD-92-16X	SHD-92-16X	SHD-92-16X	SHD-92-17X
	5 FT	0 FT	3 FT	5 FT	0 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	1620	9920	1660	1780	2790
arsenic	22.7	320	21.3	12.4	97.9
barium	< 5.18	96.8	< 5.18	< 5.18	< 5.18
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	19600	8950	20700	16600	18200
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	< 1.42	< 1.42	< 1.42	< 1.42
chromium	173	6170	114	148	301
copper	< 0.965	72.8	< 0.965	< 0.965	< 0.965
iron	2970	24200	2670	2230	8420
mercury	0.766	77	0.954	< 0.05	4.64
potassium	< 100	< 100	< 100	< 100	< 100
magnesium	1380	2120	1360	1320	1460
manganese	150	826	161	143	1000
sodium	2310	2240	2210	2350	2740
nickel	< 1.71	38.2	< 1.71	< 1.71	< 1.71
lead	17.7	200	6.44	4.31	17.2
selenium	< 0.25	6.62	< 0.25	< 0.25	< 0.25
vanadium	< 3.39	< 3.39	< 3.39	< 3.39	< 3.39
zinc	< 8.03	373	< 8.03	< 8.03	< 8.03
OTHER (ug/g)					
total organic carbon	688000	350000	675000	621000	584000
SOLIDS (% WET WT)	10.5	8.6	11.1	11.1	8.6

Notes:
< = less than

TABLE 4–5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD–92–17X	SHD–92–17X	SHD–92–18X	SHD–92–18X	SHD–92–18X
	3 FT	5 FT	0 FT	3 FT	5 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	2020	2290	4010	4550	4780
arsenic	37.3	14.5	170	49.5	34.2
barium	< 5.18	< 5.18	< 5.18	< 5.18	< 5.18
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	17700	11500	13300	7700	4030
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	< 1.42	< 1.42	< 1.42	< 1.42
chromium	104	71.6	90.3	181	< 4.05
copper	< 0.965	8.66	< 0.965	13.1	10.3
iron	9920	7220	13100	3720	1700
mercury	1.3	0.715	0.695	1.18	< 0.05
potassium	< 100	< 100	< 100	< 100	< 100
magnesium	1510	< 100	< 100	< 100	626
manganese	1320	251	1420	219	90.5
sodium	2160	2710	2460	2370	1250
nickel	< 1.71	< 1.71	< 1.71	< 1.71	14.1
lead	6.37	3.16	30.6	18.2	2.41
selenium	< 0.25	< 0.25	< 0.25	< 0.25	2.27
vanadium	< 3.39	< 3.39	< 3.39	< 3.39	< 3.39
zinc	< 8.03	< 8.03	< 8.03	< 8.03	< 8.03
OTHER (ug/g)					
total organic carbon	1840000	688000	564000	650000	302000
SOLIDS (% WET WT)	10.7	11.9	8	12.1	20.4

Notes:
< = less than

TABLE 4–5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD–92–19X	SHD–92–19X	SHD–92–20X	SHD–92–20X	SHD–92–20X
	0 FT	2 FT	0 FT	3 FT	5 FT
PESTICIDES/PCBs (ug/g)					
DDD	0.017	0.013	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	4150	2800	6620	7240	5930
arsenic	11	9.99	150	34	11.6
barium	31.7	15.3	46.8	49.4	51.8
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	1190.	562	2360	5280	4980
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	3.52	2.35	10.1	< 1.42	5.66
chromium	110	46.2	1190	93.5	41.4
copper	22.3	13.4	22.4	5.7	5.12
iron	16000	11400	10200	6630	5610
mercury	0.195	0.1	21	0.25	0.201
potassium	270	276	768	< 100	342
magnesium	1500	1040	1700	1870	1590
manganese	148	114	342	363	542
sodium	274	207	648	914	682
nickel	13.8	8.77	15.3	15.6	13.9
lead	25	17	63	9.94	4.37
selenium	0.698	0.496	2.34	1.92	1.86
vanadium	9.14	5.38	13.7	< 3.39	< 3.39
zinc	59.1	37.8	91.6	< 8.03	30.1
OTHER (ug/g)					
total organic carbon	14900	11200	110000	168000	110000
SOLIDS (% WET WT)	76.6	78.9	28.4	21.6	31.4

Notes:
< = less than

TABLE 4-5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD-92-21X	SHD-92-21X	SHD-92-21X	SHD-92-21X	SHD-92-22X
	0 FT	4 FT	4 FT (DUP)	7 FT	0 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	0.133
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	9980	5530	4780	6400	7310
arsenic	340	15.7	17.8	29.7	190
barium	94.6	48.7	43.8	57.4	46.8
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	8350	8510	8790	7540	9950
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	< 1.42	< 1.42	< 1.42	< 1.42
chromium	4100	28.2	67.2	< 4.05	467
copper	54.3	6.7	7.97	14.3	12.3
iron	18600	5910	5450	7560	10100
mercury	< 0.05	< 0.05	0.42	< 0.05	1.84
potassium	< 100	< 100	< 100	< 100	< 100
magnesium	1820	1060	903	1170	1370
manganese	785	682	701	730	520
sodium	1810	1360	1350	1200	1290
nickel	29.6	14.2	< 1.71	17.8	< 1.71
lead	170	4.25	5.22	4.04	34.1
selenium	3.91	2.35	< 0.25	3.44	2.33
vanadium	< 3.39	< 3.39	< 3.39	< 3.39	< 3.39
zinc	252	< 8.03	< 8.03	< 8.03	< 8.03
OTHER (ug/g)					
total organic carbon	384000	331000	330000	353000	288000
SOLIDS (% WET WT)	9.8	17.3	16.5	15.4	14.9

Notes:
< = less than

TABLE 4–5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD–92–22X	SHD–92–23X	SHD–92–23X	SHD–92–23X	SHD–92–24X
	3 FT	0 FT	3 FT	5 FT	0 FT
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	4300	9760	3980	936	3890
arsenic	190	470	7.62	8.03	150
barium	37.3	68.1	21.6	< 5.18	33.8
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	5320	8850	5430	5580	4140
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	< 1.42	< 1.42	< 1.42	< 1.42
chromium	1100	1510	49.6	58.6	1050
copper	16.8	29.5	4.88	3.24	13.8
iron	8920	15300	2600	2370	6780
mercury	41	18	0.371	< 0.05	8.8
potassium	< 100	< 100	< 100	< 100	< 100
magnesium	786	1900	538	295	737
manganese	484	663	136	91.1	336
sodium	708	2360	1110	472	1350
nickel	11.1	23.9	6.36	< 1.71	11.6
lead	65	180	4.35	2.72	40.7
selenium	3.14	6.37	1.73	< 0.25	1.94
vanadium	< 3.39	< 3.39	< 3.39	< 3.39	< 3.39
zinc	67.7	126	< 8.03	< 8.03	65.3
OTHER (ug/g)					
total organic carbon	182000	461000	170000	196000	158000
SOLIDS (% WET WT)	25.3	8.4	33.8	36.4	23.1

Notes:
< = less than

TABLE 4-5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD-92-24X	SHD-92-24X	SHD-92-25X	SHD-92-25X	SHD-92-25X
	3 FT	5 FT	0 FT	3 FT	3 FT (DUP)
PESTICIDES/PCBs (ug/g)					
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	< 0.008	0.047	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
INORGANICS (ug/g)					
aluminum	4820	1920	4150	6140	8290
arsenic	7.97	15.1	7.53	22.9	46
barium	23.6	< 5.18	18.1	29.7	41.2
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	3630	2770	4080	4070	5060
cadmium	< 0.7	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	< 1.42	< 1.42	< 1.42	< 1.42
chromium	28.5	23.9	24.5	149	395
copper	4.07	2.81	3.55	3.91	7.89
iron	4180	2070	1770	3310	5240
mercury	< 0.05	0.168	< 0.05	2.14	1.8
potassium	272	< 100	< 100	275	< 100
magnesium	1550	567	699	1000	1390
manganese	69.4	30.4	123	210	271
sodium	563	526	518	547	704
nickel	9.89	5.32	7.26	9.25	12.8
lead	3.02	0.873	3.88	12.5	27.7
selenium	1.35	< 0.25	1.67	1.38	1.53
vanadium	< 3.39	< 3.39	< 3.39	< 3.39	< 3.39
zinc	28.6	19.1	< 8.03	< 8.03	38.2
OTHER (ug/g)					
total organic carbon	121000	67400	156000	102000	131000
SOLIDS (% WET WT)	38	49.7	39.1	39.5	29.5

Notes:
< = less than

TABLE 4-5
SEDIMENT SAMPLE ANALYTICAL RESULTS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP IA SITES
FORT DEVENS, MA

ANALYTE	SHD-92-25X	SHD-92-26X	SHD-92-27X	SHD-92-28X
	5 FT	0 FT	0 FT	0 FT
PESTICIDES/PCBs (ug/g)				
DDD	< 0.008	< 0.008	0.18	0.28
DDE	< 0.008	< 0.008	0.075	0.041
DDT	< 0.007	< 0.007	< 0.007	0.13
INORGANICS (ug/g)				
aluminum	4320	6600	13500	3050
arsenic	10.9	170	150	310
barium	19.6	79.9	45.9	24.1
beryllium	< 0.5	< 0.5	< 0.5	< 0.5
calcium	4560	3050	3650	5180
cadmium	< 0.7	< 0.7	< 0.7	< 0.7
cobalt	< 1.42	12.6	22.4	50.8
chromium	84.9	3060	1060	132
copper	4.87	58.3	23.6	7.58
iron	2340	21600	19400	51300
mercury	0.578	31	5	0.294
potassium	< 100	572	< 100	< 100
magnesium	770	1410	2110	703
manganese	122	967	600	2370
sodium	679	899	1120	482
nickel	9.2	18.9	24.8	29.9
lead	4.49	160	100	37
selenium	1.52	2.52	< 0.25	< 0.25
vanadium	< 3.39	21.8	30.5	< 3.39
zinc	< 8.03	203	83.4	27.5
OTHER (ug/g)				
total organic carbon	166000	268000	240000	65500
SOLIDS (% WET WT)	30	22.2	13.9	38

Notes:
< = less than

TABLE 4-6

INTERPRETED SOURCES OF INORGANIC SEDIMENT CONTAMINANTS

PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT

FEASIBILITY STUDY FOR GROUP 1A SITES

FORT DEVENS, MA

	RI REPORT	RI ADDENDUM REPORT
Shepley's Hill Landfill Source	Arsenic	Arsenic*
	Iron	Iron**
	Manganese	Manganese
	Cadmium	Barium
	Barium**	Nickel
Grove Pond Source	Copper	Copper
	Chromium	Chromium***
	Lead	Lead***
	Mercury	Mercury
	Nickel	Zinc***

Notes:

* Grove Pond is interpreted as the major historical source of arsenic.

** Grove Pond may also be a source.

*** Shepley's Hill Landfill may be a minor source of these contaminants.

TABLE 4-7
SUMMARY OF PLOW SHOP POND SHALLOW SEDIMENT INORGANIC DATA

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	RI DATA SET			SUPPLEMENTAL DATA SET		
	FREQUENCY OF DETECTION	MAXIMUM VALUE	AVERAGE VALUE	FREQUENCY OF DETECTION	MAXIMUM VALUE	AVERAGE VALUE
aluminum	13/13	24000	13185	28/28	13500	5540
arsenic	13/13	3200	997	28/28	510	221
barium	13/13	310	174	25/28	344	86
beryllium	8/13	2.72	1.61	0/28	n/a	n/a
cadmium	12/13	60	31	1/28	19.2	19.2
calcium	11/13	13000	6963	28/28	20100	9041
chromium	11/13	10000	3835	27/28	6170	1454
cobalt	0/13	n/a	n/a	8/28	58.7	24
copper	9/13	132	86	21/28	105	38
iron	13/13	330000	73485	28/28	68400	19057
lead	13/13	632	241	27/28	260	78
magnesium	13/13	6900	2607	23/28	2120	1420
manganese	10/13	8800	2509	27/28	54800	3074
mercury	13/13	130	29	24/28	89	16
nickel	9/13	79.3	49	16/28	70.1	28
potassium	13/13	2350	1093	4/28	817	607
selenium	0/13	n/a	n/a	12/28	6.62	3.4
sodium	7/13	896	467	28/28	2870	1457
vanadium	9/13	165	87	6/28	61.7	26
zinc	1/13	43	43	16/28	403	191

Notes:
All concentrations in ug/g
n/a = not applicable

TABLE 4-8
METALS CONCENTRATIONS IN TCLP EXTRACTS OF SEDIMENT SAMPLES
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	REGULATORY THRESHOLD		SHD-92-03X 0 FT		SHD-92-03X 3 FT		SHD-92-08X 0 FT		SHD-92-08X 4 FT		SHD-92-08X 7 FT
METALS (mg/L)											
Arsenic	5		0.220		0.110		0.120	<	0.073	<	0.073
Barium	100		0.320		0.270		0.220		0.220		0.160
Cadmium	1	<	0.0044	<	0.0044	<	0.0044	<	0.0044	<	0.0044
Chromium	5	<	0.0074	<	0.0074	<	0.0074	<	0.0074	<	0.0074
Lead	5	<	0.064	<	0.064	<	0.064	<	0.064	<	0.064
Mercury	0.2	<	0.00018	<	0.00018	<	0.00018	<	0.00018	<	0.00018
Selenium	1	<	0.100	<	0.100	<	0.100	<	0.100	<	0.100
Silver	5	<	0.0061	<	0.0061	<	0.0061	<	0.0061	<	0.0061

Notes:
< = less than

TABLE 4-8
METALS CONCENTRATIONS IN TCLP EXTRACTS OF SEDIMENT SAMPLES
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	REGULATORY THRESHOLD		SHD-92-14X 0 FT		SHD-92-14X 14 FT
METALS (mg/L)					
Arsenic	5		0.240	<	0.073
Barium	100		0.290		0.290
Cadmium	1	<	0.0044	<	0.0044
Chromium	5	<	0.0074	<	0.0074
Lead	5	<	0.064	<	0.064
Mercury	0.2	<	0.00018	<	0.00018
Selenium	1	<	0.100	<	0.100
Silver	5	<	0.0061	<	0.0061

Notes:
< = less than

TABLE 4-9
GROUNDWATER AND SEDIMENT CHEMICALS EXCEEDING EVALUATION CRITERIA
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CONTAMINANT	GROUNDWATER (ug/L)	PLOW SHOP POND SEDIMENT (ug/g)
VOLATILE ORGANIC COMPOUNDS		
Acetone	X	
Benzene	X	
Chloroethane	X	
Dichlorobenzenes	X	
1,1-dichloroethane	X	
1,2-dichloroethane	X	
1,2-dichloroethylenes	X	
1,2-dichloropropane	X	
Toluene	X	
Trichloroethylene	X	
Trichlorofluoromethane	X	
SEMIVOLATILE ORGANIC COMPOUNDS		
Benzo(a)anthracene		X
Chrysene		X
Fluoranthene		X
Naphthalene		X
Phenanthrene		X
Pyrene		X
PESTICIDES/PCBs		
DDD		X
DDE		X
DDT		X
INORGANICS		
Aluminum	X	
Antimony	X	
Arsenic	X	X *
Barium	X	X *
Calcium	X	
Chromium	X	X
Copper	X	X
Iron	X	X *
Lead	X	X
Magnesium	X	
Manganese	X	X *
Mercury	X	X
Nickel	X	X *
Potassium	X	
Vanadium	X	
Zinc	X	X

Notes:

Semivolatile organic compound contamination in sediment based on the RI Report (E&E, 1993).

* Shepley's Hill Landfill is an interpreted source of these contaminants.

TABLE 4-10
CONCENTRATIONS OF CHEMICALS IN PLOW SHOP POND SURFACE WATER

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM CONCENTRATION
VOLATILE ORGANIC COMPOUNDS (ug/L)		
Chloroform	6/12	1.41
Methylene Chloride	12/13	8.92
PESTICIDES/PCBs (ug/L)		
alpha-Benzenehexachloride	13/13	0.07
Endrin	1/13	0.008
INORGANICS (ug/L)		
Arsenic	13/13	6.84
Barium	13/13	11.8
Calcium	13/13	13000
Copper	11/13	48.7
Iron	13/13	538
Magnesium	13/13	2300
Manganese	13/13	139
Nickel	7/13	44.2
Potassium	13/13	1100
Silver	2/13	3.6
Sodium	13/13	25000
Zinc	4/13	58.1

NOTES:
Methylene chloride, alpha-benzenehexachloride, and endrin attributed to laboratory contamination.

SOURCE: E&E, 1993

TABLE 4-11
LANDFILL GAS ANALYTICAL RESULTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE IDENTIFICATION DATE DEPTH (ft)	SG-1 (μg/L) 01/28/93 3	SG-2 (μg/L) 01/28/93 10	SG-3 (μg/L) 01/28/93 10
Benzene	< 1.0	< 1.0	< 1.0
Toluene	< 1.0	< 1.0	< 1.0
Ethylbenzene	< 1.0	< 1.0	< 1.0
m/p-Xylene	< 2.0	< 2.0	< 2.0
o-Xylene	< 1.0	< 1.0	< 1.0
Methane	< 1.0	< 1.0	< 1.0
Vinyl Chloride	< 5.0	< 5.0	< 5.0
1,1-Dichloroethene	< 1.0	< 1.0	< 1.0
Methylene Chloride	< 1.0	< 1.0	< 1.0
T-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	< 1.0	< 1.0	< 1.0
C-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
Chloroform	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	< 5.0	< 5.0	< 5.0
1,2-Dichloroethane	< 1.0	< 1.0	< 1.0
Trichloroethene	< 1.0	< 1.0	< 1.0
Tetrachloroethene	< 1.0	< 1.0	< 1.0
1,1,2,2-Tetrachloroethane	< 1.0	< 1.0	< 1.0

(continued)

TABLE 4-11
LANDFILL GAS ANALYTICAL RESULTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE IDENTIFICATION DATE DEPTH (ft)	SG-4 (μg/L) 01/28/93 10	SG-5 (μg/L) 01/28/93 3	SG-6 (μg/L) 01/28/93 3
Benzene	< 1.0	< 1.0	< 1.0
Toluene	< 1.0	< 1.0	< 1.0
Ethylbenzene	< 1.0	< 1.0	< 1.0
m/p-Xylene	< 2.0	< 2.0	< 2.0
o-Xylene	< 1.0	< 1.0	< 1.0
Methane	< 1.0	< 1.0	< 1.0
Vinyl Chloride	< 5.0	< 5.0	< 5.0
1,1-Dichloroethene	< 1.0	< 1.0	< 1.0
Methylene Chloride	< 1.0	< 1.0	< 1.0
T-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	< 1.0	< 1.0	< 1.0
C-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
Chloroform	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	< 5.0	< 5.0	< 5.0
1,2-Dichloroethane	< 1.0	< 1.0	< 1.0
Trichloroethene	< 1.0	< 1.0	< 1.0
Tetrachloroethene	< 1.0	< 1.0	< 1.0
1,1,2,2-Tetrachloroethane	< 1.0	< 1.0	< 1.0

(continued)

TABLE 4-11
LANDFILL GAS ANALYTICAL RESULTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE IDENTIFICATION DATE DEPTH (ft)	SG-7 (µg/L) 01/28/93 10	SG-8 (µg/L) 01/28/93 10	SG-9 (µg/L) 01/28/93 10
Benzene	< 1.0	N/A	< 1.0
Toluene	< 1.0	N/A	< 1.0
Ethylbenzene	< 1.0	N/A	< 1.0
m/p-Xylene	< 2.0	N/A	< 2.0
o-Xylene	< 1.0	N/A	< 1.0
Methane	< 1.0	16,000	97
Vinyl Chloride	< 5.0	N/A	< 5.0
1,1-Dichloroethene	< 1.0	N/A	< 1.0
Methylene Chloride	< 1.0	N/A	< 1.0
T-1,2-Dichloroethene	< 1.0	N/A	< 1.0
1,1-Dichloroethane	< 1.0	N/A	< 1.0
C-1,2-Dichloroethene	< 1.0	N/A	< 1.0
Chloroform	< 1.0	N/A	< 1.0
1,1,1-Trichloroethane	< 5.0	N/A	< 5.0
1,2-Dichloroethane	< 1.0	N/A	< 1.0
Trichloroethene	< 1.0	N/A	< 1.0
Tetrachloroethene	< 1.0	N/A	< 1.0
1,1,2,2-Tetrachloroethane	< 1.0	N/A	< 1.0

(continued)

TABLE 4-11
LANDFILL GAS ANALYTICAL RESULTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE IDENTIFICATION DATE DEPTH (ft)	SG-10 (µg/L) 01/29/93 3	SG-11 (µg/L) 01/29/93 3	SG-12 (µg/L) 01/29/93 10
Benzene	1.0	11	< 1.0
Toluene	< 1.0	< 1.0	< 1.0
Ethylbenzene	< 1.0	< 1.0	< 1.0
m/p-Xylene	< 2.0	< 2.0	< 2.0
o-Xylene	< 1.0	< 1.0	< 1.0
Methane	110,000	(8,200)	(2,200)
Vinyl Chloride	< 5.0	< 5.0	< 5.0
1,1-Dichloroethene	< 1.0	< 1.0	< 1.0
Methylene Chloride	< 1.0	< 1.0	< 1.0
T-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	< 1.0	< 1.0	< 1.0
C-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
Chloroform	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	< 5.0	< 5.0	< 5.0
1,2-Dichloroethane	< 1.0	< 1.0	< 1.0
Trichloroethene	< 1.0	< 1.0	< 1.0
Tetrachloroethene	< 1.0	< 1.0	< 1.0
1,1,2,2-Tetrachloroethane	< 1.0	< 1.0	< 1.0

(continued)

TABLE 4-11
LANDFILL GAS ANALYTICAL RESULTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE IDENTIFICATION DATE DEPTH (ft)	SG-13 (µg/L) 01/29/93 10	SG-14 (µg/L) 01/29/93 10	SG-15 (µg/L) 01/29/93 10
Benzene	< 1.0	< 1.0	< 1.0
Toluene	< 1.0	< 1.0	< 1.0
Ethylbenzene	< 1.0	< 1.0	< 1.0
m/p-Xylene	< 2.0	< 2.0	< 2.0
o-Xylene	< 1.0	< 1.0	< 1.0
Methane	(16)	< 1.0	(13,000)
Vinyl Chloride	< 5.0	< 5.0	< 5.0
1,1-Dichloroethene	< 1.0	< 1.0	< 1.0
Methylene Chloride	< 1.0	< 1.0	< 1.0
T-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	< 1.0	< 1.0	< 1.0
C-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
Chloroform	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	< 5.0	< 5.0	< 5.0
1,2-Dichloroethane	< 1.0	< 1.0	< 1.0
Trichloroethene	< 1.0	< 1.0	< 1.0
Tetrachloroethene	< 1.0	< 1.0	< 1.0
1,1,2,2-Tetrachloroethane	< 1.0	< 1.0	< 1.0

(continued)

TABLE 4-11
LANDFILL GAS ANALYTICAL RESULTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE IDENTIFICATION DATE DEPTH (ft)	SG-16 (μg/L) 01/28/93 6	VENT-1 (μg/L) 01/28/93 N/A	VENT-2 (μg/L) 01/29/93 N/A
Benzene	< 1.0	< 1.0	1.5
Toluene	< 1.0	< 1.0	< 1.0
Ethylbenzene	< 1.0	< 1.0	< 1.0
m/p-Xylene	< 2.0	< 2.0	< 2.0
o-Xylene	< 1.0	< 1.0	< 1.0
Methane	< 1.0	2.0	(690)
Vinyl Chloride	< 5.0	< 5.0	< 5.0
1,1-Dichloroethene	< 1.0	< 1.0	< 1.0
Methylene Chloride	< 1.0	< 1.0	< 1.0
T-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	< 1.0	< 1.0	< 1.0
C-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
Chloroform	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	< 5.0	< 5.0	< 5.0
1,2-Dichloroethane	< 1.0	< 1.0	< 1.0
Trichloroethene	< 1.0	< 1.0	< 1.0
Tetrachloroethene	< 1.0	< 1.0	< 1.0
1,1,2,2-Tetrachloroethane	< 1.0	< 1.0	< 1.0

(continued)

TABLE 4-11
LANDFILL GAS ANALYTICAL RESULTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SAMPLE IDENTIFICATION DATE DEPTH (ft)	VENT-3 (μg/L) 01/29/93 N/A	VENT-4(μg/L) 01/29/93 N/A	VENT-5 (μg/L) 01/29/93 N/A
Benzene	< 1.0	< 1.0	1.5
Toluene	< 1.0	< 1.0	< 1.0
Ethylbenzene	< 1.0	< 1.0	< 1.0
m/p-Xylene	< 2.0	< 2.0	< 2.0
o-Xylene	< 1.0	< 1.0	< 1.0
Methane	(210)	(180)	< 1.0
Vinyl Chloride	< 5.0	< 5.0	< 5.0
1,1-Dichloroethene	< 1.0	< 1.0	< 1.0
Methylene Chloride	< 1.0	< 1.0	< 1.0
T-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
1,1-Dichloroethane	< 1.0	< 1.0	< 1.0
C-1,2-Dichloroethene	< 1.0	< 1.0	< 1.0
Chloroform	< 1.0	< 1.0	< 1.0
1,1,1-Trichloroethane	< 5.0	< 5.0	< 5.0
1,2-Dichloroethane	< 1.0	< 1.0	< 1.0
Trichloroethene	< 1.0	< 1.0	< 1.0
Tetrachloroethene	< 1.0	< 1.0	< 1.0
1,1,2,2-Tetrachloroethane	< 1.0	< 1.0	< 1.0

Note:

( ) = Estimated value; result corrected for methane sorbtion.

TABLE 4–12
SURFACE WATER SAMPLE ANALYTICAL RESULTS
GROVE POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	GRW–92–01X	GRW–92–02X	GRW–92–03X	GRW–92–04X	GRW–92–05X
ORGANICS (ug/L)					
trichloroethylene / trichloroethene	< 0.5	< 0.5	< 0.5	0.5	< 0.5
INORGANICS (ug/L)					
aluminum	< 141	< 141	< 141	2960	< 141
arsenic	< 2.54	< 2.54	< 2.54	4.05	< 2.54
barium	34.1	20.6	18.1	42.3	33.8
calcium	9450	9310	11200	19700	15500
iron	156	485	671	841	451
potassium	2070	1370	1360	2570	2600
magnesium	1930	1770	1640	2730	1850
manganese	16.7	71.7	748	178	72.5
sodium	22000	19400	21100	18100	15500
lead	2.06	< 1.26	< 1.26	6.18	4.23
OTHER (ug/L)					
alkalinity	153000	NA	NA	8000	37000
total hardness	30400	NA	NA	54800	47600
total dissolved solids	102000	NA	NA	132000	110000
total organic carbon	NA	4690	5790	NA	NA
total suspended solids	< 4000	7000	76000	80000	< 4000

Notes:
< = less than
NA = not analyzed

TABLE 4-13
SEDIMENT SAMPLE ANALYTICAL RESULTS
GROVE POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	GRD-92-01X	GRD-92-02X	GRD-92-03X	GRD-92-04X	GRD-92-05X
	0 FT	0 FT	0 FT	0 FT	0 FT
ORGANICS (ug/g)					
acetone	0.046	0.81	0.32	< 0.017	0.13
toluene	< 0.001	0.013	< 0.001	< 0.001	< 0.001
2-methylnaphthalene	< 0.2	< 0.049	< 0.049	0.7	< 0.5
4-methylphenol / 4-cresol	< 1	12	17	< 1	< 2
acenaphthylene	< 0.2	< 0.033	< 0.033	0.3	< 0.3
anthracene	< 0.2	< 0.033	< 0.033	0.4	< 0.3
chrysene	< 0.6	< 0.12	< 0.12	2	< 1
fluoranthene	< 0.3	< 0.068	< 0.068	3	< 0.7
fluorene	< 0.2	< 0.033	< 0.033	0.6	< 0.3
naphthalene	< 0.2	3.7	5.6	0.8	< 0.4
phenanthrene	< 0.2	0.5	0.44	3	< 0.3
pyrene	< 0.2	< 0.033	< 0.033	2	< 0.3
PESTICIDES/PCBs					
DDD	0.034	ND 0.270 R	ND 0.270 R	0.15	< 0.008
DDE	0.024	ND 0.310 R	ND 0.310 R	0.016	< 0.008
DDT	< 0.007	ND 0.310 R	ND 0.310 R	0.015	< 0.007
INORGANICS (ug/g)					
aluminum	4450	10900	8160	8540	6430
arsenic	23	350	910	11.6	3.09
barium	23.2	181	156	35.3	83.3
calcium	1440	18000	12000	1760	24800
cadmium	< 0.7	8.16	< 0.7	< 0.7	< 0.7
cobalt	3.63	18.1	< 1.42	3.1	< 1.42
chromium	692	19900	26100	23.8	< 4.05
copper	15.5	79.9	98.6	13	< 0.965
iron	6620	25400	20000	9210	1180
mercury	2	260 L	420 L	< 0.05	< 0.05
potassium	712	< 100	< 100	757	< 100
magnesium	1320	1730	1340	2440	890
manganese	68.6	783	313	55.3	1640
sodium	311	2400	3110	289	727
nickel	8.97	36.9	23.2	12.9	< 1.71
lead	50	390	38.8	27	4.26
selenium	< 0.25	3.99	4.44	< 0.25	3.19
vanadium	11.2	43.6	< 3.39	13	< 3.39
zinc	80.8	447	303	28.6	< 8.03
OTHER (ug/g)					
total organic carbon	81600	NA	NA	11100	505000
SOLIDS (% WET WT)	55.6	10	10.8	52.3	20.8

Notes:
< = Less than
L = Missed holding time for analysis.
NA = Not analyzed
R = Analyte required for reporting purposes, but not currently certified
ND = not detectable

TABLE 4-14

WETLAND SHALLOW GROUNDWATER SAMPLE ANALYTICAL RESULTS

NONACOICUS BROOK

REMEDIAL INVESTIGATION ADDENDUM REPORT

FEASIBILITY STUDY FOR GROUP 1A SITES

FORT DEVENS, MA

ANALYTE		SHW-92-01X UNFILTERED		SHW-92-01X FILTERED		SHW-92-02X UNFILTERED		SHW-92-02X FILTERED
INORGANICS (ug/L)								
aluminum	<	141		1220		2000	<	141
arsenic	<	2.54		2.98		4.69	<	2.54
barium		33.3		19.9		30.7		14.7
calcium		2370		2380		3430		3390
chromium	<	6.02	<	6.02	<	6.02	<	6.02
copper	<	8.09	<	8.09	<	8.09	<	8.09
iron	<	38.8		566		1830		67.8
mercury	<	0.243	<	0.243	<	0.243	<	0.243
potassium		1280		530		1540		908
magnesium		1470		1490		2840		2720
manganese		29.8		41.4		70.5		51.5
sodium		1320		1320		1550		1460
lead		1.74		1.84		4.01	<	1.26
vanadium	<	11	<	11	<	11	<	11
zinc	<	21.1	<	21.1	<	21.1	<	21.1
OTHER (ug/L)								
alkalinity	<	5000				19000		
total hardness		12000				18000		
total dissolved solids		28000				46000		
total organic carbon		2420				6620		
total suspended solids		17000				25000		

Notes:

< = less than

TABLE 4-14
WETLAND SHALLOW GROUNDWATER SAMPLE ANALYTICAL RESULTS
NONACOICUS BROOK

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	SHW-92-03X UNFILTERED	SHW-92-03X FILTERED	SHW-92-04X UNFILTERED	SHW-92-04X FILTERED
INORGANICS (ug/L)				
aluminum	5240	< 141	18800	230
arsenic	24.9	< 2.54	22.3	< 2.54
barium	71.8	25.6	136	67
calcium	28300	25900	10100	8800
chromium	15.3	< 6.02	32.7	< 6.02
copper	< 8.09	< 8.09	19	< 8.09
iron	7830	173	14700	84.6
mercury	0.581	< 0.243	0.886	< 0.243
potassium	3440	2530	2050	1160
magnesium	3790	3410	1690	744
manganese	322	65	541	417
sodium	2590	2340	2490	2230
lead	43.1	< 1.26	81.7	5.53
vanadium	13.5	< 11	23.9	< 11
zinc	39.2	< 21.1	251	160
OTHER (ug/L)				
alkalinity	86000		< 5000	
total hardness	72400		26400	
total dissolved solids	160000		80000	
total organic carbon	18100		21500	
total suspended solids	104000		8440000	

Notes:
< = less than

TABLE 4-15
WETLAND SOIL SAMPLE ANALYTICAL RESULTS
NONACOICUS BROOK

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	SHD-92-29X	SHD-92-29X	SHD-92-30X	SHD-92-30X	SHD-92-31X
	0 FT	2 FT	0 FT	2 FT	0 FT
VOLATILE ORGANIC COMPOUNDS (ug/g)					
Trichlorofluoromethane	< 0.006	< 0.006	< 0.006	0.008	< 0.006
PESTICIDES/PCBs (ug/g)					
PPDDE	< 0.076	< 0.008	< 0.076	< 0.008	0.03
PPDDT	< 0.071	< 0.007	< 0.071	< 0.007	< 0.071
INORGANICS (ug/g)					
aluminum	6660	5270	9070	7460	14500
arsenic	20	7.74	18.8	8.83	28
barium	23.3	< 5.18	30.8	7.15	43.7
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	1.25
calcium	1010	143	1770	187	2850
cobalt	2.67	2.2	3.46	1.98	6.51
chromium	89.5	8.32	51	8.81	31.8
copper	9.54	3.95	14.8	3.52	17.6
iron	6870	5150	9330	5780	14600
mercury	1.9	< 0.05	0.966	< 0.05	0.369
potassium	223	175	464	223	1150
magnesium	1000	1040	1580	911	3230
manganese	212	50.3	175	51.1	340
silver	< 0.589	< 0.589	< 0.589	< 0.589	< 0.589
sodium	274	183	364	224	330
nickel	7.55	7.19	10.1	7.77	18.7
lead	42	3.23	57	7.28	39
selenium	< 0.25	< 0.25	0.677	< 0.25	< 0.25
vanadium	13.2	5.51	18.5	7.22	21.7
zinc	22.3	< 8.03	33.9	14.6	56.9
OTHER (ug/g)					
total organic carbon	47100	5110	116000	8530	59300
SOLIDS (% WET WT)	66.2	82.7	54.8	80.3	59.2

Notes:
< = Less than

TABLE 4-15
WETLAND SOIL SAMPLE ANALYTICAL RESULTS
NONACOICUS BROOK

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	SHD-92-31X	SHD-92-32X	SHD-92-32X
	1 FT	0 FT	0 FT
VOLATILE ORGANIC COMPOUNDS (ug/g)			
Trichlorofluoromethane	< 0.006	< 0.006	< 0.006
PESTICIDES/PCBs (ug/g)			
PPDDE	0.029	0.17	< 0.076
PPDDT	0.015	0.042	0.028
INORGANICS (ug/g)			
aluminum	2440	8490	8680
arsenic	7.65	18.1	16.4
barium	23.3	55.4	53.3
beryllium	< 0.5	< 0.5	< 0.5
calcium	2790	904	712
cobalt	< 1.42	< 1.42	3.15
chromium	22.4	22.7	19.8
copper	6.65	13.1	11.8
iron	3920	7910	8470
mercury	0.582	0.57	0.405
potassium	237	295	269
magnesium	388	816	741
manganese	155	79.8	103
silver	< 0.589	1.22	< 0.589
sodium	334	343	279
nickel	< 1.71	9.53	8.07
lead	31	82	54
selenium	< 0.25	0.679	< 0.25
vanadium	< 3.39	14.9	12.1
zinc	23.9	77.7	64.8
OTHER (ug/g)			
total organic carbon	53300	64300	61800
SOLIDS (% WET WT)	57.6	54.9	60

Notes:
< = Less than

TABLE 4-16
METALS CONCENTRATIONS IN TCLP EXTRACTS OF WETLAND SOILS
NONACOICUS BROOK

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	REGULATORY THRESHOLD	SHD-92-29X 0 FT		SHD-92-30X 0 FT	
METALS (mg/L)					
Arsenic	5.000	<	0.073	<	0.073
Barium	100.000		0.200		0.300
Cadmium	1.000	<	0.004	<	0.004
Chromium	5.000		0.008	<	0.007
Lead	5.000	<	0.064	<	0.064
Mercury	0.200	<	0.000	<	0.000
Selenium	1.000	<	0.100	<	0.100
Silver	5.000	<	0.006	<	0.006

Notes:
< = less than

TABLE 4-17
ROUND 1 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CSB-1 UNFILTERED	CSB-2 UNFILTERED	CSB-2 FILTERED	CSB-3 UNFILTERED	CSB-3 FILTERED	CSB-5 UNFILTERED	CSB-6 UNFILTERED
PESTICIDES/PCBs (ug/L)							
bis (2-ethylhexyl) phthalate	< 4.8	< 4.8		< 4.8		84	< 4.8
INORGANICS (ug/L)							
aluminum	6930	195	< 141	5760	< 141	5700	12400
arsenic	8.21	< 2.54	< 2.54	14.8	< 2.54	92.5	6.82
barium	35.9	18.6	11.4	27.7	7.54	145	53.5
calcium	14400	62500	61000	22000	20000	82200	15100
cobalt	35	< 25	< 25	< 25	< 25	< 25	< 25
chromium	10.4	< 6.02	< 6.02	25.1	< 6.02	9.84	16.4
copper	11.1	< 8.09	< 8.09	10.9	< 8.09	< 8.09	10.3
iron	13900	667	176	8040	51.8	6140	8350
potassium	2010	4150	3690	3530	1520	2780	1940
magnesium	3570	11400	11700	6160	3660	15600	4120
manganese	4880	5700	6120	120	5.58	292	104
sodium	3310	16200	15500	4070	3210	17000	29000
nickel	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3	< 34.3
lead	3.8	3.9	< 1.26	3.25	< 1.26	7.59	9.33
vanadium	< 11	< 11	11.9	14.6	< 11	< 11	11.6
zinc	90.6	< 21.1	< 21.1	27	< 21.1	52.2	36.6
OTHER (ug/L)							
alkalinity	35000	175000	NA	57000	NA	246000	32000
total hardness	49200	208000	NA	260000	NA	262000	89000
total dissolved solids	72000	282000	NA	115000	NA	345000	132000
total organic carbon	4960	5040	NA	2200	NA	NA	5200
total suspended solids	24000	22000	NA	320000	NA	802000	452000

Notes:
< = Less than
NA = not analyzed

TABLE 4-17
ROUND 1 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CSB-7 UNFILTERED	CSB-7 (DUP) UNFILTERED	CSB-8 UNFILTERED	CSB-8 FILTERED	CSM-93-01A UNFILTERED	CSM-93-01A FILTERED
PESTICIDES/PCBs (ug/L)						
bis (2-ethylhexyl) phthalate	< 4.8	< 4.8	< 4.8		< 4.8	
INORGANICS (ug/L)						
aluminum	2070	3460	23900	< 141	< 141	< 141
arsenic	8	13.4	28	< 2.54	25.9	6.4
barium	19.5	25.7	212	103	49	22.5
calcium	3850	3950	36600	31300	164000	109000
cobalt	< 25	< 25	< 25	< 25	< 25	< 25
chromium	< 6.02	< 6.02	47.2	< 6.02	< 6.02	< 6.02
copper	< 8.09	< 8.09	28.7	< 8.09	< 8.09	< 8.09
iron	2600	4230	27700	< 38.8	23500	4000
potassium	< 375	2100	4740	485	7250	17000
magnesium	1230	1610	9180	2020	28900	18900
manganese	69.9	108	522	15.8	3750	2110
sodium	14600	14500	232000	211000	21100	18100
nickel	< 34.3	< 34.3	63.3	< 34.3	< 34.3	< 34.3
lead	1.52	2.06	11.5	< 1.26	< 1.26	< 1.26
vanadium	< 11	< 11	29	< 11	< 11	< 11
zinc	< 21.1	< 21.1	61.1	< 21.1	< 21.1	< 21.1
OTHER (ug/L)						
alkalinity	8000	10000	46000	NA	293000	NA
total hardness	12000	8000	101000	NA	546000	NA
total dissolved solids	90000	86000	733000	NA	429000	NA
total organic carbon	1050	< 1000	3390	NA	10300	NA
total suspended solids	251000	167000	2030000	NA	< 4000	NA

Notes:
< = Less than
NA = not analyzed

TABLE 4-17
ROUND 1 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CSM-93-02A UNFILTERED	CSM-93-02A FILTERED	CSM-93-02B UNFILTERED	PATTON WELL UNFILTERED
PESTICIDES/PCBs (ug/L)				
bis (2-ethylhexyl) phthalate	< 4.8		14	
INORGANICS (ug/L)				
aluminum	20500	< 141	285	< 141
arsenic	40	< 2.54	< 2.54	3.2
barium	112	10.6	14.8	5.31
calcium	5200	3920	39700	43400
cobalt	< 25	< 25	< 25	< 25
chromium	30.8	<	< 6.02	< 6.02
copper	31	< 8.09	22.3	20
iron	25400	< 38.8	383	152
potassium	5450	1710	8430	3780
magnesium	6080	790	3710	5310
manganese	655	63.9	354	288
sodium	6730	5810	19000	12100
nickel	49	< 34.3	< 34.3	< 34.3
lead	13.4	< 1.26	2.06	< 1.26
vanadium	26.3	< 11	< 11	< 11
zinc	60.1	< 21.1	< 21.1	< 21.1
OTHER (ug/L)				
alkalinity	40000	NA	157000	122000
total hardness	36000	NA	114000	133000
total dissolved solids	57000	NA	327000	216000
total organic carbon	< 1000	NA	2240	2200
total suspended solids	47800	NA	11000	8000

Notes:
< = Less than
NA = not analyzed

TABLE 4-18
ROUND 2 GROUNDWATER ANALYTICAL RESULTS SUMMARY FOR
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CSM-93-01A UNFILTERED	CSM-93-01A UNFILTERED (DUP)	CSM-93-01A FILTERED	CSM-93-01A FILTERED (DUP)	CSM-93-02A UNFILTERED	CSM-93-02B UNFILTERED
PESTICIDES/PCBs (ug/L)						
bis (2-ethylhexyl) phthalate	< 4.8	4.4 (1)			< 4.8	< 4.8
INORGANICS (ug/L)						
aluminum	< 141	< 141	< 141	< 141	10200	< 141
arsenic	17.2	19.2	19.8	16.6	22.6	< 2.54
barium	34.2	35.2	36.8	36.2	65.7	15.6
calcium	139000	140000	148000	148000	4870	76000
chromium	< 6.02	< 6.02	< 6.02	< 6.02	15.2	< 6.02
copper	< 8.09	< 8.09	< 8.09	< 8.09	17.4	< 8.09
iron	13900	13600	14600	14500	12300	82.1
potassium	8130	8540	7740	7830	2690	3980
magnesium	23500	23800	25000	24900	3210	10000
manganese	3200	3210	3430	3410	294	376
sodium	17600	17700	18600	18300	4870	42900
lead	< 1.26	< 1.26	< 1.26	< 1.26	7.81	< 1.26
zinc	< 21.1	< 21.1	< 21.1	< 21.1	32.2	< 21.1
OTHER (ug/L)						
alkalinity	408000	202000			7000	182000
total hardness	422000	434000			12400	218000
total organic carbon	8080	6390			< 1000	2800
total dissolved solids	542000	526000			36000	354000
total suspended solids	46000	39000			214000	4000

Notes:

(1) = Results less than CRL, but greater than COD

ug/L = micrograms per Liter

DUP = Duplicate sample

< = Less than

TABLE 4-19
ANALYTICAL RESULTS FOR WATER SAMPLES AT COLD SPRING BROOK LANDFILL
SEEPS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CSW-92-01X UNFILTERED	CSW-92-01X FILTERED	CSW-92-02X UNFILTERED	CSW-92-02X FILTERED	CSW-92-03X UNFILTERED	CSW-92-03X FILTERED
PESTICIDES/PCBs (ug/L)						
DDD	0.081		< 0.023		< 0.023	
INORGANICS (ug/L)						
aluminum	4700	< 141	74500	< 141	2420	< 141
arsenic	590	270	130	96	6.29	< 2.54
barium	119	44.9	226	25.7	209	16.9
calcium	67800	56900	43500	36700	59100	57400
cobalt	< 25	< 25	41.9	< 25	< 25	< 25
chromium	7.23	< 6.02	132	< 6.02	10.9	< 6.02
copper	14.1	< 8.09	92.1	< 8.09	< 8.09	< 8.09
iron	70700	31100	125000	24800	2100	< 38.8
mercury	0.243	< 0.243	< 0.243	< 0.243	< 0.243	< 0.243
potassium	3700	3560	9070	1850	2790	2700
magnesium	6900	6730	25100	3240	7970	7610
manganese	3410	2910	1170	510	98.6	48.1
sodium	6960	7810	26600	24500	13600	13300
nickel	< 34.3	< 34.3	155	< 34.3	< 34.3	< 34.3
lead	75.7	< 1.26	58.9	< 1.26	14.4	< 1.26
vanadium	20.5	< 11	103	< 11	< 11	< 11
zinc	141	< 21.1	308	< 21.1	26	< 21.1
OTHER (ug/L)						
alkalinity	44000		34000		147000	
total dissolved solids	232000		204000		254000	
total hardness	162000		93000		164000	
total organic carbon	23700		14100		4290	
total suspended solids	1080000		2880000		220000	

Notes:

< = Less than

TABLE 4-20
FREQUENCY OF DETECTION FOR ANALYTES IN SAMPLES
CSW-92-01X, -02X, AND -03X

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM CONCENTRATION
DDD	1/3	0.081
aluminum	3/3	74500
arsenic	3/3	590
barium	3/3	226
calcium	3/3	67800
chromium	3/3	132
cobalt	1/3	41.9
copper	2/3	92.1
iron	3/3	125000
lead	3/3	75.7
magnesium	3/3	25000
manganese	3/3	3410
mercury	1/3	0.243
nickel	1/3	155
potassium	3/3	9070
sodium	3/3	26600
vanadium	2/3	103
zinc	3/3	308

TABLE 4-21
SEDIMENT SAMPLE ANALYTICAL RESULTS
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CSD-92-01X	CSD-92-01X	CSD-92-01X	CSD-92-01X	CSD-92-02X	CSD-92-02X	CSD-92-02X
	0 FT	2 FT	2 FT (DUP)	3 FT	0 FT	2 FT	4 FT
ORGANICS (ug/g)							
acenaphthene	< 0.9	< 0.9	< 0.9	< 0.036	< 0.9	< 0.036	< 0.036
acenaphthylene	< 0.8	< 0.8	2	< 0.033	< 0.8	< 0.033	< 0.033
anthracene	< 0.8	< 0.8	2	< 0.033	< 0.8	< 0.033	< 0.033
benzo [a] anthracene	< 4	< 4	10	< 0.17	< 4	< 0.17	< 0.17
benzo [a] pyrene	< 6	< 6	10	< 0.25	< 6	< 0.25	< 0.25
benzo [b] fluoranthene	< 5	< 5	9	< 0.21	< 5	< 0.21	< 0.21
benzo [k] fluoranthene	< 2	4	10	0.11	7	< 0.066	< 0.066
9h-carbazole	ND 2	ND 2 R	ND 2 R	ND 0.1 R	ND 2 R	ND 0.1 R	ND 0.1 R
chrysene	< 3	8	20	0.23	< 3	< 0.12	< 0.12
dibenzofuran	< 0.9	< 0.9	< 0.9	< 0.035	< 0.9	< 0.035	< 0.035
fluoranthene	10	10	20	0.26	10	< 0.068	< 0.068
fluorene	< 0.8	< 0.8	2	< 0.033	< 0.8	< 0.033	< 0.033
naphthalene	< 0.9	< 0.9	< 0.9	< 0.037	< 0.9	< 0.037	< 0.037
phenanthrene	5	4	10	0.14	6	< 0.033	< 0.033
pyrene	10	10	30	0.37	20	< 0.033	< 0.033
PESTICIDES/PCBs (ug/g)							
Dieldrin	< 0.006	0.009	< 0.13	< 0.006	< 0.006	< 0.006	< 0.007
DDD	6.2	2.3	4.7	0.15	1.2	< 0.008	< 0.008
DDE	0.72	0.055	0.45	0.015	0.35	< 0.008	< 0.008
DDT	15	0.42	0.9	0.022	0.4	< 0.007	< 0.007
EXPLOSIVES (ug/g)							
nitroglycerine	< 4	< 4	< 4	< 4	< 4	< 4	< 4
INORGANICS (ug/g)							
aluminum	15800	8370	17600	3250	6170	2210	2800
arsenic	82	11	24	6.3	72	2.93	1.92
barium	115	24.1	54.4	12.4	29.4	< 5.18	13
beryllium	< 0.5	< 0.5	1.04	< 0.5	< 0.5	< 0.5	< 0.5
calcium	6100	923	2160	686	5650	453	528
cobalt	18.5	7.04	12.6	< 1.42	6.73	< 1.42	< 1.42
chromium	64.8	24.6	41.3	11	21.2	8.73	7.96
copper	42.9	13	27.8	1.95	26.5	2.37	4.43
iron	36400	14800	19100	3520	19300	2870	3680
potassium	3580	834	1620	339	671	276	301
magnesium	7160	4770	5960	1270	1880	1060	1290
manganese	522	141	301	47.6	216	32	42.8
silver	6.35	< 0.589	< 0.589	< 0.589	< 0.589	< 0.589	< 0.589
sodium	1860	236	325	180	624	189	193
nickel	54.3	36.4	45.6	6.52	16.1	5.66	7.71
lead	570	38	60	3.5	91	1.82	2.61
antimony	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09
selenium	< 0.25	< 0.25	< 0.25	< 0.25	1.2	< 0.25	< 0.25
vanadium	48.6	15.6	31	4.65	19.2	< 3.39	4.94
zinc	291	48.8	96.1	< 8.03	96.3	< 8.03	< 8.03
OTHER (ug/g)							
total organic carbon	140000	19000	47100	1700	156000	878	998
SOLIDS (% WET WT)	27.5	73.2	71.6	83.5	29.7	84.7	84.8

Notes: < = less than
R = Analyte required for reporting purposes, but not currently certified
S = Results based on internal standard
ND = not detected

TABLE 4-21
SEDIMENT SAMPLE ANALYTICAL RESULTS
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CSD-92-03X	CSD-92-03X	CSD-92-03X	CSD-92-04X	CSD-92-04X	CSD-92-04X	CSD-92-05X
	0 FT	3 FT	5 FT	0 FT	3 FT	5 FT	0 FT
ORGANICS (ug/g)							
acenaphthene	< 0.2	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036
acenaphthylene	< 0.2	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
anthracene	< 0.2	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
benzo [a] anthracene	< 0.8	< 0.17	< 0.17	< 0.17	< 0.17	< 0.17	< 0.17
benzo [a] pyrene	< 1	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
benzo [b] fluoranthene	< 1	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21
benzo [k] fluoranthene	< 0.3	< 0.066	< 0.066	< 0.066	< 0.066	< 0.066	< 0.066
9h-carbazole	ND 0.5 R	ND 0.1 R	ND 0.1 R	ND 0.1 R	ND 0.1 R	ND 0.1 R	ND 0.1 R
chrysene	< 0.6	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12
dibenzofuran	< 0.2	< 0.035	< 0.035	< 0.035	< 0.035	< 0.035	< 0.035
fluoranthene	< 0.3	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068
fluorene	< 0.2	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
naphthalene	< 0.2	< 0.037	< 0.037	< 0.037	< 0.037	< 0.037	< 0.037
phenanthrene	< 0.2	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
pyrene	< 0.2	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
PESTICIDES/PCBs (ug/g)							
Dieldrin	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
DDD	0.49	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDE	0.071	< 0.008	< 0.008	< 0.008	< 0.008	< 0.021	< 0.008
DDT	0.14	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
EXPLOSIVES (ug/g)							
nitroglycerine	< 4	< 4	< 4	< 4	< 4	< 4	< 4
INORGANICS (ug/g)							
aluminum	4960	2470	3170	4520	2530	3050	3210
arsenic	18.1	12.4	6.84	16.4	5.2	2.85	4.15
barium	21.4	< 5.18	9.34	15.4	< 5.18	11.2	< 5.18
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	6480	669	1150	1580	517	1260	486
cobalt	< 1.42	3.58	3.4	< 1.42	3.35	4.35	< 1.42
chromium	< 4.05	13.8	8.84	9.83	7.13	9.61	< 4.05
copper	< 0.965	2.45	5.77	2.58	3.99	6.23	< 0.965
iron	6280	4960	4820	6440	3090	4400	2240
potassium	206	351	561	392	312	475	< 100
magnesium	745	1270	1520	1350	1030	1600	637
manganese	622	44.6	54.8	369	40.2	61.3	45.7
silver	< 0.589	< 0.589	< 0.589	< 0.589	< 0.589	< 0.589	< 0.589
sodium	316	188	216	327	182	226	212
nickel	3.99	8.57	11.3	7.3	11	12.3	3.38
lead	17.8	2.83	3	6.49	2.58	2.9	4.36
antimony	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09
selenium	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
vanadium	< 3.39	7.88	6.75	7.1	< 3.39	7.54	< 3.39
zinc	< 8.03	< 8.03	12.2	19.1	< 8.03	12.9	< 8.03
OTHER (ug/g)							
total organic carbon	156000	883	450	100000	618	555	60600
SOLIDS (% WET WT)	54.7	83	83.2	55.4	85	82.9	78.1

Notes: < = less than
R = Analyte required for reporting purposes, but not currently certified
S = Results based on internal standard
ND = not detected

TABLE 4-21
SEDIMENT SAMPLE ANALYTICAL RESULTS
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CSD-92-05X	CSD-92-05X	CSD-92-06X	CSD-92-06X	CSD-92-06X	CSD-92-07X	CSD-92-07X
	2 FT	4 FT	0 FT	2 FT	4 FT	0 FT	2 FT
ORGANICS (ug/g)							
acenaphthene	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036	< 0.2	< 0.2
acenaphthylene	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.2	< 0.2
anthracene	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.2	< 0.2
benzo [a] anthracene	< 0.17	< 0.17	< 0.17	< 0.17	< 0.17	< 0.8	< 0.8
benzo [a] pyrene	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 1	< 1
benzo [b] fluoranthene	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 1	< 1
benzo [k] fluoranthene	< 0.066	< 0.066	< 0.066	< 0.066	< 0.066	< 0.3	< 0.3
9h-carbazole	ND 0.1 R	ND 0.1 R	ND 0.1 R	ND 0.1 R	ND 0.1 R	ND 0.5 R	ND 0.5 R
chrysene	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.6	< 0.6
dibenzofuran	< 0.035	< 0.035	< 0.035	< 0.035	< 0.035	< 0.2	< 0.2
fluoranthene	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068	< 0.3	< 0.3
fluorene	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.2	< 0.2
naphthalene	< 0.037	< 0.037	< 0.037	< 0.037	< 0.037	< 0.2	< 0.2
phenanthrene	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.2	< 0.2
pyrene	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.2	< 0.2
PESTICIDES/PCBs (ug/g)							
Dieldrin	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
DDD	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	0.106	< 0.008
DDE	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
EXPLOSIVES (ug/g)							
nitroglycerine	< 4	< 4	< 4	< 4	< 4	< 4	< 4
INORGANICS (ug/g)							
aluminum	2930	4120	3980	2860	3190	1400	2870
arsenic	1.73	1.97	3.5	1.12	22	390	910
barium	< 5.18	11.8	7.21	6.75	13.4	55.1	< 5.18
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	430	682	1280	660	1610	33600	28200
cobalt	< 1.42	2.82	< 1.42	< 1.42	3.68	19.6	11.6
chromium	6.49	8.99	8.28	9.55	8.6	< 4.05	< 4.05
copper	2.87	5.7	2.63	3.17	6.47	< 0.965	9.82
iron	3000	4400	3840	3390	6640	17900	6570
potassium	184	454	238	269	603	< 100	< 100
magnesium	1060	1440	1260	1350	1540	2090	1960
manganese	27.5	60.3	134	27.8	138	1640	1350
silver	< 0.589	< 0.589	< 0.589	< 0.589	< 0.589	< 0.589	5.26
sodium	186	210	206	183	229	1330	1090
nickel	5.99	9.31	6.31	6.57	13.5	42.6	72.2
lead	2.31	3.2	2.66	2.41	2.82	31.2	1.63
antimony	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	15.8
selenium	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	5.67	15.2
vanadium	< 3.39	6.47	5.05	4.63	7.57	< 3.39	33.6
zinc	< 8.03	11.7	11.7	< 8.03	14.3	87.1	< 8.03
OTHER (ug/g)							
total organic carbon	4020	677	10300	290	238	817000	512000
SOLIDS (% WET WT)	83.6	81.5	79.4	84.9	82.8	10.5	13.5

Notes: < = less than
R = Analyte required for reporting purposes, but not currently certified
S = Results based on internal standard
ND = not detected

TABLE 4-21
SEDIMENT SAMPLE ANALYTICAL RESULTS
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CSD-92-08X	CSD-92-08X	CSD-92-09X	CSD-92-09X	CSD-92-09X	CSD-92-09X	CSD-92-10X
	0 FT	2 FT	0 FT	3 FT	3 FT (DUP)	5 FT	0 FT
ORGANICS (ug/g)							
acenaphthene	< 0.2	< 0.2	0.87	1.2	1.3	0.12	< 0.036
acenaphthylene	< 0.2	< 0.2	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
anthracene	< 0.2	< 0.2	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
benzo [a] anthracene	< 0.8	< 0.8	< 0.17	< 0.17	< 0.17	< 0.17	< 0.17
benzo [a] pyrene	< 1	< 1	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
benzo [b] fluoranthene	< 1	< 1	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21
benzo [k] fluoranthene	< 0.3	< 0.3	< 0.066	< 0.066	< 0.066	< 0.066	< 0.066
9h-carbazole	ND 0.5 R	ND 0.5 R	ND 0.1 R	ND 0.1 R	0.71 S	ND 0.1 R	ND 0.1 R
chrysene	< 0.6	< 0.6	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12
dibenzofuran	< 0.2	< 0.2	0.61	0.82	0.91	< 0.035	< 0.035
fluoranthene	< 0.3	< 0.3	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068
fluorene	< 0.2	< 0.2	1	1.3	1.5	0.13	< 0.033
naphthalene	< 0.2	< 0.2	< 0.037	< 0.037	0.33	< 0.037	< 0.037
phenanthrene	< 0.2	< 0.2	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
pyrene	< 0.2	< 0.2	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
PESTICIDES/PCBs (ug/g)							
Dieldrin	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
DDD	0.37	< 0.008	0.141	< 0.008	< 0.008	< 0.008	< 0.008
DDE	0.073	< 0.008	< 0.008	< 0.08	< 0.008	< 0.008	< 0.008
DDT	0.084	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007	< 0.007
EXPLOSIVES (ug/g)							
nitroglycerine	< 4	< 4	< 4	< 4	< 4	< 4	< 4
INORGANICS (ug/g)							
aluminum	2280	1980	2420	6380	3170	3040	3030
arsenic	250	230	250	170	100	3.92	3.78
barium	82.3	44.3	75.6	92.7	56	20.7	14.7
beryllium	< 0.5	< 0.5	< 0.5	6.84	< 0.5	2.07	< 0.5
calcium	20800	44200	28400	36400	19200	7060	611
cobalt	< 1.42	< 1.42	14.7	59.1	17.7	< 1.42	1.92
chromium	< 4.05	< 4.05	< 4.05	405	165	144	12.3
copper	11.6	7.76	< 0.965	19.2	9.98	5.45	2.9
iron	38100	6390	37700	22600	12500	3560	4700
potassium	1090	< 100	838	1030	< 100	371	510
magnesium	1130	1860	1440	1790	1000	751	1550
manganese	1320	136	1720	1980	1080	310	66.6
silver	< 0.589	4.37	< 0.589	6.8	< 0.589	1.42	0.881
sodium	1220	975	1130	1130	977	288	152
nickel	< 1.71	< 1.71	16.4	89.1	33.6	14.5	9.64
lead	120	16	33.3	23.7	10.6	3.34	2.77
antimony	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09
selenium	4.39	6.32	< 0.25	11.2	5.63	< 0.25	< 0.25
vanadium	< 3.39	24.5	< 3.39	< 3.39	< 3.39	< 3.39	6.41
zinc	237	< 8.03	151	90	< 8.03	< 8.03	14.2
OTHER (ug/g)							
total organic carbon	788000	763000	697000	615000	595000	29800	7140
SOLIDS (% WET WT)	11.7	15.2	12.7	12.3	15.8	52.1	82.4

Notes: < = less than
R = Analyte required for reporting purposes, but not currently certified
S = Results based on internal standard
ND = not detected

TABLE 4-21
SEDIMENT SAMPLE ANALYTICAL RESULTS
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CSD-92-10X	CSD-92-11X	CSD-92-11X	CSD-92-12X	CSD-92-12X	CSD-92-13X	CSD-92-13X
	2 FT	0 FT	1 FT	0 FT	1 FT	0 FT	1 FT
ORGANICS (ug/g)							
acenaphthene	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036	< 0.036
acenaphthylene	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
anthracene	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
benzo [a] anthracene	< 0.17	< 0.17	< 0.17	< 0.17	< 0.17	< 0.17	< 0.17
benzo [a] pyrene	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25	< 0.25
benzo [b] fluoranthene	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21	< 0.21
benzo [k] fluoranthene	< 0.066	< 0.066	< 0.066	< 0.066	< 0.066	< 0.066	< 0.066
9h-carbazole	ND 0.1 R	ND 0.1 R	ND 0.1 R	ND 0.1 R	ND 0.1 R	ND 0.1 R	ND 0.1 R
chrysene	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12
dibenzofuran	< 0.035	< 0.035	< 0.035	< 0.035	< 0.035	< 0.035	< 0.035
fluoranthene	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068	< 0.068
fluorene	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
naphthalene	< 0.037	< 0.037	< 0.037	< 0.037	< 0.037	< 0.037	< 0.037
phenanthrene	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
pyrene	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033	< 0.033
PESTICIDES/PCBs (ug/g)							
Dieldrin	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
DDD	< 0.008	< 0.008	< 0.008	< 0.083	0.06	< 0.008	< 0.008
DDE	< 0.008	0.115	< 0.008	< 0.076	0.023	< 0.008	< 0.008
DDT	< 0.007	< 0.007	< 0.007	0.011	0.023	< 0.007	< 0.007
EXPLOSIVES (ug/g)							
nitroglycerine	< 4						
INORGANICS (ug/g)							
aluminum	2410	2240	1520	4700	5820	4200	3350
arsenic	7.5	78	99	20	22	7.51	6.46
barium	10.4	55.3	< 5.18	14.6	16.1	10.9	10.1
beryllium	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
calcium	488	36300	32200	860	1080	1000	748
cobalt	1.89	< 1.42	< 1.42	2.51	2.74	2.28	1.9
chromium	8.33	< 4.05	< 4.05	13.3	18.1	27	19.9
copper	2.93	8.91	< 0.965	5.56	4.28	2.03	1.66
iron	3760	13300	7170	10600	7790	7180	5770
potassium	438	889	< 100	305	344	363	290
magnesium	1020	1600	1760	1900	2300	2060	1340
manganese	40.8	1110	94.3	73.8	86	64	47
silver	0.882	4.3	< 0.589	< 0.589	< 0.589	< 0.589	< 0.589
sodium	167	1190	1080	190	190	203	181
nickel	6.31	< 1.71	< 1.71	13.3	11.9	8.72	6.78
lead	2.46	8.09	5.36	6.4	6.64	4.06	4.01
antimony	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09	< 1.09
selenium	< 0.25	4.62	6.72	< 0.25	< 0.25	< 0.25	< 0.25
vanadium	4.75	< 3.39	< 3.39	8.48	10	7.41	6.62
zinc	11.2	< 8.03	< 8.03	28.1	28.1	14.6	11.8
OTHER (ug/g)							
total organic carbon	920	585000	627000	13900	23200	1940	9820
SOLIDS (% WET WT)	85.1	14.3	15.1	83.9	83.9	83.3	82.4

Notes: < = less than
R = Analyte required for reporting purposes, but not currently certified
S = Results based on internal standard
ND = not detected

TABLE 4-21
SEDIMENT SAMPLE ANALYTICAL RESULTS
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE		CSD-92-14X			CSD-92-15X			CSD-92-16X	
		0 FT			0 FT			0 FT	
ORGANICS (ug/g)									
acenaphthene	<	0.2		<	0.2		<	0.2	
acenaphthylene	<	0.2		<	0.2		<	0.2	
anthracene	<	0.2		<	0.2		<	0.2	
benzo [a] anthracene	<	0.8		<	0.8		<	0.8	
benzo [a] pyrene	<	20		<	1		<	1	
benzo [b] fluoranthene	<	1		<	1		<	1	
benzo [k] fluoranthene	<	0.3		<	0.3		<	0.3	
9h-carbazole	ND	0.5	R	ND	0.5	R	ND	0.5	R
chrysene	<	0.6		<	0.6		<	0.6	
dibenzofuran	<	0.2		<	0.2		<	0.2	
fluoranthene	<	0.3		<	0.3		<	0.3	
fluorene	<	0.2		<	0.2		<	0.2	
naphthalene	<	0.2		<	0.2		<	0.2	
phenanthrene	<	0.2		<	0.2		<	0.2	
pyrene	<	0.2		<	0.2		<	0.2	
PESTICIDES/PCBs (ug/g)									
Dieldrin	<	0.006		<	0.006		<	0.006	
DDD	<	0.008			0.031			0.15	
DDE	<	0.008			0.013			0.034	
DDT	<	0.007			0.061		<	0.007	
EXPLOSIVES (ug/g)									
nitroglycerine		11.3		<	4		<	4	
INORGANICS (ug/g)									
aluminum		2100			8110			6400	
arsenic		280			11.9			15	
barium		73.2			30.9			18.3	
beryllium	<	0.5		<	0.5		<	0.5	
calcium		41600			2030			1790	
cobalt	<	1.42			6.29		<	1.42	
chromium		49.2			23.4			7.5	
copper	<	0.965			7.53		<	0.965	
iron		7280			10600			4860	
potassium	<	100			702			225	
magnesium		1860			3660			951	
manganese		1020			230			181	
silver	<	0.589			0.773		<	0.589	
sodium		995			236			192	
nickel	<	1.71			21.7			4.95	
lead		11.6			7.7			11.4	
antimony	<	1.09		<	1.09		<	1.09	
selenium		5.77		<	0.25		<	0.25	
vanadium	<	3.39			14			5.75	
zinc	<	8.03			39.6			19.3	
OTHER (ug/g)									
total organic carbon		471000			9160			23500	
SOLIDS (% WET WT)		15.3			74.6			67.6	

Notes: < = less than
R = Analyte required for reporting purposes, but not currently certified
S = Results based on internal standard
ND = not detected

TABLE 4-22
SUMMARY OF COLD SPRING BROOK POND SHALLOW SEDIMENT INORGANIC DATA

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	RI DATA SET FREQUENCY OF DETECTION	RI DATA SET MAXIMUM VALUE	RI DATA SET AVERAGE VALUE	SUPPLEMENTAL DATA SET FREQUENCY OF DETECTION	SUPPLEMENTAL DATA SET MAXIMUM VALUE	SUPPLEMENTAL DATA SET AVERAGE VALUE
INORGANICS						
aluminum	9/9	17000	8578	16/16	15800	4720
arsenic	9/9	160	50	16/16	390	94
barium	9/9	67.4	33	15/16	115	41
beryllium	1/9	0.36	0.36	0/16	n/a	n/a
calcium	4/9	13000	2600	16/16	41600	11785
chromium	5/9	50.7	25	10/16	64.8	24
cobalt	0/9	n/a	n/a	8/16	18.6	9.1
copper	6/9	34.9	10	10/16	42.9	11
iron	9/9	45000	17122	16/16	38100	14170
lead	9/9	345	90	16/16	570	58
magnesium	9/9	7000	2764	16/16	7160	1955
manganese	9/9	3000	723	16/16	1720	583
mercury	6/9	0.718	0.16	0/16	n/a	n/a
nickel	3/9	26.3	5.6	13/16	54.3	16
potassium	9/9	3000	892	13/16	3580	770
selenium	0/9	n/a	n/a	5/16	5.77	4.3
silver	0/9	n/a	n/a	4/16	6.35	4.1
sodium	4/9	403	88	16/16	1860	649
vanadium	9/9	41.1	19	9/16	48.6	14
zinc	5/9	690	97	12/16	291	84

Notes:
All concentrations in ug/g
n/a = not applicable
Values for samples SE-CSB-06 and SE-CSB-06D averaged before consideration in this table

TABLE 4-23
COMPARISON OF COLD SPRING BROOK POND SHALLOW SEDIMENT INORGANIC DATA TO EVALUATION CRITERIA

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	EVALUATION CRITERIA	RI DATA SET			SUPPLEMENTAL DATA SET		
		DETECTION FREQUENCY	MAXIMUM VALUE	EXCEEDANCE FREQUENCY	DETECTION FREQUENCY	MAXIMUM VALUE	EXCEEDANCE FREQUENCY
aluminum	n/a	9/9	17000	n/a	16/16	15800	n/a
arsenic	3	9/9	160	9/9	16/16	390	16/16
barium	20	9/9	67.4	7/9	15/16	115	9/16
beryllium	n/a	1/9	0.36	n/a	0/16	n/a	n/a
calcium	n/a	4/9	13000	n/a	16/16	41600	n/a
chromium	25	5/9	50.7	2/9	10/16	64.8	2/16
cobalt	n/a	0/9	n/a	n/a	8/16	18.6	n/a
copper	25	6/9	34.9	1/9	10/16	42.9	2/16
iron	17000	9/9	45000	3/9	16/16	38100	5/16
lead	40	9/9	345	6/9	16/16	570	3/16
magnesium	n/a	9/9	7000	n/a	16/16	7160	n/a
manganese	300	9/9	3000	9/9	16/16	1720	8/16
mercury	0.10	6/9	0.718	6/9	0/16	n/a	n/a
nickel	20	3/9	26.3	1/9	13/16	54.3	3/16
potassium	n/a	9/9	3000	n/a	13/16	3580	n/a
selenium	n/a	0/9	n/a	n/a	5/16	5.77	n/a
silver	n/a	0/9	n/a	n/a	4/16	6.35	n/a
sodium	n/a	4/9	403	n/a	16/16	1860	n/a
vanadium	n/a	9/9	41.1	n/a	9/16	48.6	n/a
zinc	90	5/9	690	1/9	12/16	291	4/16

Notes:
All values in ug/g.
n/a = not applicable
Values for samples SE-CSB-06 and SE-CSB-06D averaged before consideration in this table.

TABLE 4-24
METALS CONCENTRATIONS IN TCLP EXTRACTS OF SEDIMENT SAMPLES
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	REGULATORY THRESHOLD	CSD-92-01X 0 FT	CSD-92-09X 0 FT	CSD-92-09X 3 FT	CSD-92-11X 0 FT	CSD-92-12X 0 FT
METALS (mg/L)						
Arsenic	5	0.120	0.170	0.120	0.110	0.081
Barium	100	0.430	0.120	0.230	0.140	0.170
Cadmium	1	< 0.0044	< 0.0044	< 0.0044	< 0.0044	< 0.0044
Chromium	5	< 0.0074	< 0.0074	< 0.0074	< 0.0074	< 0.0074
Lead	5	0.140	< 0.064	< 0.064	< 0.064	< 0.064
Mercury	0.2	< 0.00018	< 0.00018	< 0.00018	< 0.00018	< 0.00018
Selenium	1	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Silver	5	< 0.0061	< 0.0061	< 0.0061	< 0.0061	< 0.0061

Notes:
< = less than

TABLE 4-25
CONCENTRATIONS OF CHEMICALS IN COLD SPRING BROOK POND SURFACE WATER

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM CONCENTRATION
VOLATILE ORGANIC COMPOUNDS (ug/L)		
Methylene Chloride	9/9	8.14
PESTICIDES/PCBs (ug/L)		
alpha-Benzenehexachloride	1/9	0.02
INORGANICS (ug/L)		
Arsenic	9/9	17.7
Barium	9/9	13.4
Calcium	9/9	31000
Chromium	2/9	4.76
Copper	7/9	6.75
Iron	9/9	3200
Magnesium	9/9	3300
Manganese	9/9	400
Potassium	9/9	2010
Silver	1/9	0.708
Zinc	3/9	86.3

NOTES:
Methylene chloride and alpha-benzenehexachloride attributed to laboratory contamination.

SOURCE: E&E, 1993

TABLE 4-26
GROUNDWATER, SEDIMENT, AND SOIL CHEMICALS EXCEEDING EVALUATION CRITERIA
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CONTAMINANT	GROUNDWATER (ug/L)	POND SEDIMENT (ug/g)	SURFACE SOIL (ug/g)
VOLATILE ORGANIC COMPOUNDS			
2-Butanone		X	
SEMIVOLATILE ORGANIC COMPOUNDS			
Acenaphthene		X	
Acenaphthylene		X	
Anthracene		X	X
Benzo(a)anthracene		X	X
Benzo(a)pyrene		X	X
Benzo(b)fluoranthene		X	X
Benzo(k)fluoranthene		X	X
Benzo(g,h,i) perylene			X
Bis(2-ethylhexyl)phthalate	X	X	
9h-Carbazole		X	
Chrysene		X	X
Dibenzofuran		X	
Fluoranthene		X	X
Fluorene		X	
Indeno(1,2,3-C,D) pyrene			X
Naphthalene		X	
Phenanthrene		X	X
Pyrene		X	X
PESTICIDES/PCBs			
DDD		X	X
DDE		X	
DDT		X	X
INORGANICS			
Arsenic	X	X	X
Barium		X	X
Calcium	X		X
Chromium	X	X	X
Copper	X	X	X
Iron		X	X
Lead	X	X	
Magnesium	X		X
Manganese	X	X	X
Mercury			X
Nickel		X	X
Potassium	X		X
Sodium	X		X
Vanadium	X		X
Zinc	X	X	X

Notes:
Surface soil contaminants based on RI Report (E&E, 1993).

TABLE 4-27
SHALLOW GROUNDWATER SAMPLE ANALYTICAL RESULTS
MAGAZINE AREA

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	MAW-92-01X UNFILTERED	MAW-92-01X FILTERED	MAW-92-03X UNFILTERED	MAW-92-03X FILTERED
PESTICIDES/PCBs (ug/L)				
bis (2-ethylhexyl) phthalate	17		< 4.8	
DDD	0.024		< 0.023	
INORGANICS (ug/L)				
aluminum	14100	< 141	9320	1160
arsenic	26.3	3.41	31	27
barium	65.4	61	53.4	151
calcium	19500	18800	5830	5590
chromium	18.1	< 6.02	15.2	< 6.02
copper	8.38	< 8.09	25.1	12.1
iron	11600	60.3	17200	10000
potassium	2630	1860	3450	2540
magnesium	5050	2430	3570	1340
manganese	114	42.1	356	308
sodium	26300	26700	5560	5610
lead	14.4	< 1.26	26.8	23.2
vanadium	16	< 11	15.3	< 11
zinc	60.4	< 21.1	60	44.9
OTHER (ug/L)				
alkalinity	40000		10000	
total dissolved solids	166000		38000	
total hardness	51600		21200	
total suspended solids	46000		278000	

Notes:
< = Less than

TABLE 4-28
SOIL SAMPLE ANALYTICAL RESULTS
MAGAZINE AREA

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	MAD-92-01X		MAD-92-02X		MAD-92-03X
	0 FT		0 FT		0 FT
ORGANICS (ug/g)					
acenaphthylene	0.7	<	0.033	<	0.2
anthracene	0.8	<	0.033	<	0.2
benzo [a] anthracene	4	<	0.17	<	0.8
benzo [a] pyrene	4	<	0.25	<	1
benzo [b] fluoranthene	9	<	0.21	<	1
benzo [g,h,i] perylene	4	<	0.25	<	1
benzo [k] fluoranthene	4	<	0.066	<	0.3
chrysene	8	<	0.12	<	0.6
fluoranthene	7		0.15		1
phenanthrene	5		0.045	<	0.2
pyrene	10		0.09		1
PESTICIDES/PCBs (ug/g)					
PPDDD	0.073	<	0.008		0.057
PPDDE	0.093	<	0.008		0.021
PPDDT	0.35		0.009		0.034
INORGANICS (ug/g)					
aluminum	26500		7170		12800
arsenic	140		22		11.8
barium	81.6		21		38
calcium	2030		443		1710
cobalt	20.5		5.01		4.85
chromium	67.9		21.5		35.1
copper	50		8.42		19.6
iron	46700		11300		12100
potassium	2620		909		1160
magnesium	10100		3300		5450
manganese	269		202		147
sodium	532		158		318
nickel	80.8		17.9		29.3
lead	58		12		31
vanadium	45.7		14.7		23.7
zinc	205		35.3		85.6
OTHER (ug/g)					
total organic carbon	29500		2480		51800
SOLIDS (% WET WT)	54.5		92.5		53.3

Notes:
< = Less than

TABLE 4-29
SEDIMENT SAMPLE ANALYTICAL RESULTS
NEW CRANBERRY POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CRD-92-01X		CRD-92-01X		CRD-92-02X		CRD-92-03X	
	0 FT		0 FT (DUP)		0 FT		0 FT	
ORGANICS (ug/g)								
toluene		0.001	<	0.001	<	0.001	<	0.001
phenol	<	0.11	<	0.11		0.87	<	0.11
PESTICIDES/PCBs (ug/g)								
PPDDD	<	0.008	<	0.008	<	0.59		0.122
PPDDE	<	0.008	<	0.008	<	0.26		0.044
PPDDT	<	0.007	<	0.007	<	0.14		0.017
INORGANICS (ug/g)								
aluminum		6850		8350		11100		6580
arsenic		5.75		7.14		13.8		3.85
barium		16		17.5		57.4		27.7
calcium		232		197		1850		797
cobalt	<	1.42		3.07	<	1.42	<	1.42
chromium		7.06		8.91	<	4.05	<	4.05
copper		2.46		2.19		13.9		5.08
iron		4960		6170		7140		3690
mercury	<	0.05	<	0.05		0.218		0.124
potassium		290		366		575		461
magnesium		675		897		891		891
manganese		36.9		39.1		109		36.6
sodium		203		198		726		318
nickel		5.05		5.22	<	1.71		5.21
lead		4.98		7.59		97		23
vanadium		8.22		9.73		24.5		10.4
zinc		15.4		17.2		54.8		22.5
OTHER (ug/g)								
total organic carbon		9280		10000		100000		70700
SOLIDS (% WET WT)		76		78		22.8		45

Notes:
< = Less than

5.0 FATE AND TRANSPORT OF CONTAMINANTS

The conceptual model of the two landfills is essentially the same. Landfill constituents are transported from the landfills as a result of several processes including infiltration of precipitation, groundwater migration, surface soil runoff, volatilization, and discharge to surface waters. Infiltration of precipitation through the landfill will leach soluble chemicals from the landfill and introduce them into the groundwater. Groundwater will transport soluble chemicals either by passing through the waste or through the area of the aquifer containing the chemical leached during infiltration. Groundwater may also flow to the surface in seeps as a result of the pressure difference experienced when flowing downgradient or from confined to unconfined conditions. Groundwater at both Shepley's Hill Landfill and Cold Spring Brook Landfill also discharges to surface water bodies, Plow Shop Pond, and Cold Spring Brook Pond. Chemicals can volatilize from uncapped soils, seeps, and surface water.

The mobility of chemicals under the landfills or in the surface waters is determined by the physical and chemical properties of the chemicals. Organic compounds at landfills can be grouped into two primary classes: (1) mobile in groundwater, that is, those with moderate to high water solubility and limited sorption capability (low K_{oc}); and (2) immobile compounds, that is, those with low water solubility and high sorption capability. The mobile organic compounds are also volatile and the immobile compounds are the semivolatile compounds, generally PAHs.

The behavior of the inorganic compounds is more complex. Several metals (i.e., iron, arsenic, manganese, and chromium) associated with the landfills and ponds can occur in several forms and oxidation states in the range of environmental conditions characterizing the landfills and ponds. Several metals or elements can coprecipitate with each other and form a variety of complexes making an exact determination of individual species and forms impractical. For example, arsenic can form insoluble arsenates with several metal cations, such as CaAsO4 and FeAsO4. Arsenic, mercury, and antimony can also form mobile and VOCs under microbial action. These are primarily biomethylation reactions. The kinetics of the complexation and reduction reactions are also important and can control the speciation of different elements. For example, Cr(VI) is thermodynamically stable at typical pHs and oxidizing environmental conditions, but the insoluble oxide of

Cr(III) is oxidized so slowly, that once Cr(III) is formed, it persists and will often be the predominant form of chromium.

Summaries of the properties and expected fates of the contaminants identified at Shepley's Hill Landfill and Cold Spring Brook Landfill are given in Tables 5-1 and 5-2.

Organics. The organic compounds detected in the groundwater at Shepley's Hill Landfill are the volatile chlorinated organics: 1,1-dichloroethane, 1,2-dichloroethane, 1,2-dichloroethylene, 1,2-dichloropropane, chloroethane, chloroform, trichloroethylene, and benzene. No SVOCs, pesticides and PCBs, or explosives were detected in the groundwater. The VOCs originate in some of the wastes buried in the landfill. They are mobile and will be expected to migrate with the groundwater under Shepley's Hill Landfill east toward Plow Shop Pond and north toward Nonacoicus Brook. Once in the surface water and sediments, these chemicals will volatilize and not persist in the water or sediment.

The semivolatile organics, mostly PAHs and pesticides (DDD, DDE, and DDT) present in the sediments of Plow Shop Pond and Cold Spring Brook Pond are generally insoluble in water and sorb strongly to soils and sediments. Once in the sediments, they are unlikely to migrate except with the sediments. Aerobic biodegradation of the pesticides does occur, but is expected to be slow, over years. Anaerobic biodegradation of both the pesticides and PAHs is also slow, but does occur.

Bis(2-ethylhexyl)phthalate was reported in both the groundwater and sediments at Cold Spring Brook Landfill. Bis(2-ethylhexyl)phthalate is relatively insoluble in water, has a large sorption coefficient (K_{oc}), and so is expected to sorb strongly to soils, especially those with high organic matter as in the sediments. It is likely that the Bis(2-ethylhexyl)phthalate detected in groundwater samples is sorbed to the suspended solids in the samples and is not dissolved in the water.

Inorganics. **Metals**. Many of the metals on the PAL form complexes with carbonates and organic ligands. The stability of these complexes in water systems determines the equilibrium form of metals. Some of the metals also form insoluble oxides, carbonates, and sulfides in natural water systems or are present as coprecipitated solids in other metal systems. A summary of the principal species and their transport potentials in Shepley's Hill Landfill, Plow Shop Pond,

and Cold Spring Brook Landfill and Pond is presented in Table 5-2. Some of the more pertinent fates and species are described below.

Both filtered and unfiltered groundwater samples were collected at the two landfills. Concentrations of several metals were lower in the filtered samples indicating that at least a portion of the metal was present as a solid in the groundwater sample. Concentrations that were the same in both filtered and unfiltered samples indicate the metal was present as a soluble species in the groundwater. Of the metals on the PAL, calcium, magnesium, potassium and sodium form soluble salts and are expected primarily in dissolved forms.

Aluminum forms many pH-dependent complexes in water and also forms solid hydroxide and oxide. Aluminum is expected to be present primarily in the insoluble oxide or hydroxide and in a higher concentration in the unfiltered samples. The TSS and aluminum correlate well in samples collected during the supplemental RI activities.

Barium forms an insoluble oxide and hydroxide and is primarily expected in the insoluble form and will be higher in the unfiltered samples.

Chromium can exist as both the III and VI species in natural waters, and both species form complexes with organic ligands. Although Cr(VI) is more stable under typical natural systems, at least part of the Cr(VI) can be reduced by other elements. Cr(III) is kinetically favored, and once formed, will persist. Generally, chromium in surface water and groundwater exists predominantly as the insoluble Cr_2O_3; chromium dissolved in water exists as Cr(VI) and may be complexed by organic and inorganic ligands.

Arsenic, iron, and manganese speciation and solubility depend on both pH and the oxidation potential, Eh. Typically, soluble Fe(II) predominates in anaerobic groundwaters, along with As (III) and Mn(II). When anaerobic waters, including groundwaters, are exposed to oxygen, insoluble oxidized species form. As(V) coprecipitates with the iron and manganese oxides and higher concentrations of all three species are often observed at groundwater seeps. However, arsenic can be biomethylated by bacteria and other microbes present in soils and sediments. Once methylated, arsenic compounds are again mobile and may even volatilize. The concentrations of arsenic, manganese, and iron in the dissolved phase at Shepley's Hill Landfill correlate well because the oxidation potentials of all three

dissolved species are similar. Arsenic, manganese, and iron are all expected to be found in groundwater, surface water, sediments, and soils. Arsenic can be expected in air as well.

Mercury exists predominantly as Hg(II) and forms soluble and insoluble compounds. Biotransformation and eventual volatilization of methylated mercury is a dominant transport pathway. However, in the presence of sulfur, the very insoluble HgS forms, which may be sufficiently stable to resist biomethylation. Consequently, mercury can be expected in all the transport pathways: groundwater, surface water, soils, sediment, and air.

Anions. Chlorides, nitrates, nitrites, sulfates, and bromides were reported in the groundwater at Shepley's Hill Landfill and Cold Spring Brook Landfill in the ESE RI report. Metal complexes with these anions are possible at both landfills. In this study, both hardness and alkalinity were measured in the unfiltered water samples. Carbonates and bicarbonates both form complexes with many of the metals (Table 5-2) and in a large part determine the form and migration of some of the metals at the landfills.

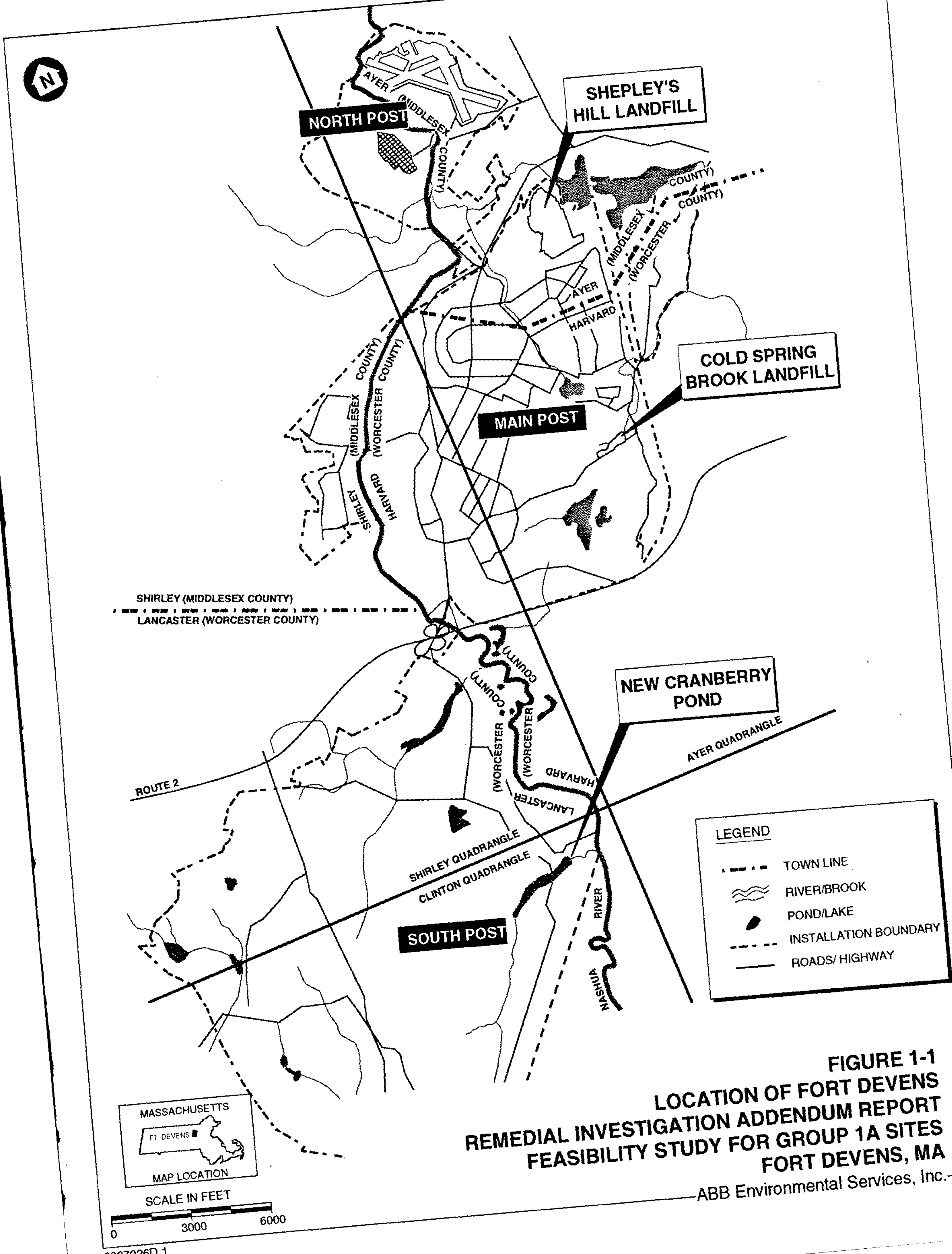

FIGURE 1-1
LOCATION OF FORT DEVENS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

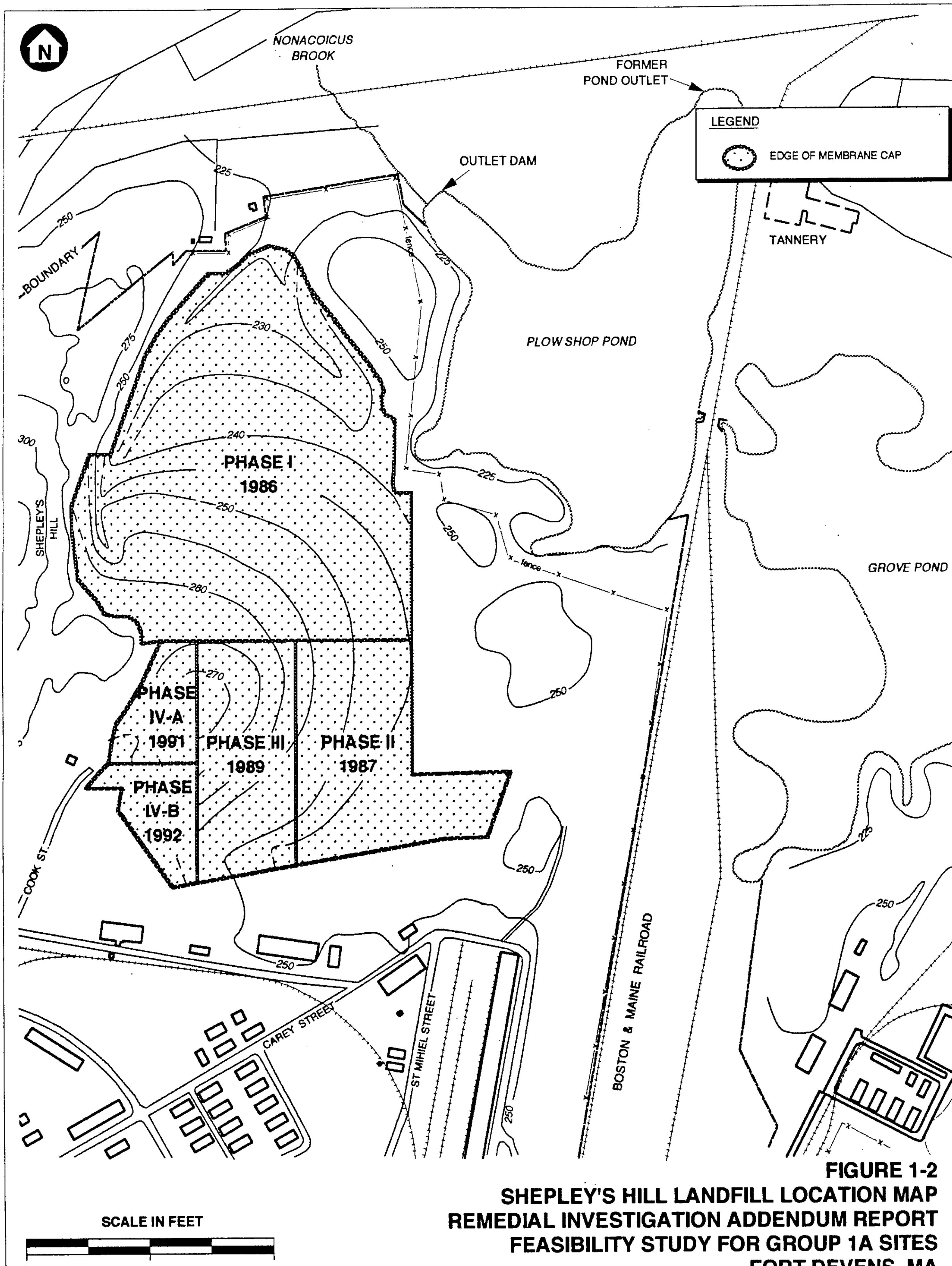

FIGURE 1-2
SHEPLEY'S HILL LANDFILL LOCATION MAP
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9303022D 1SE

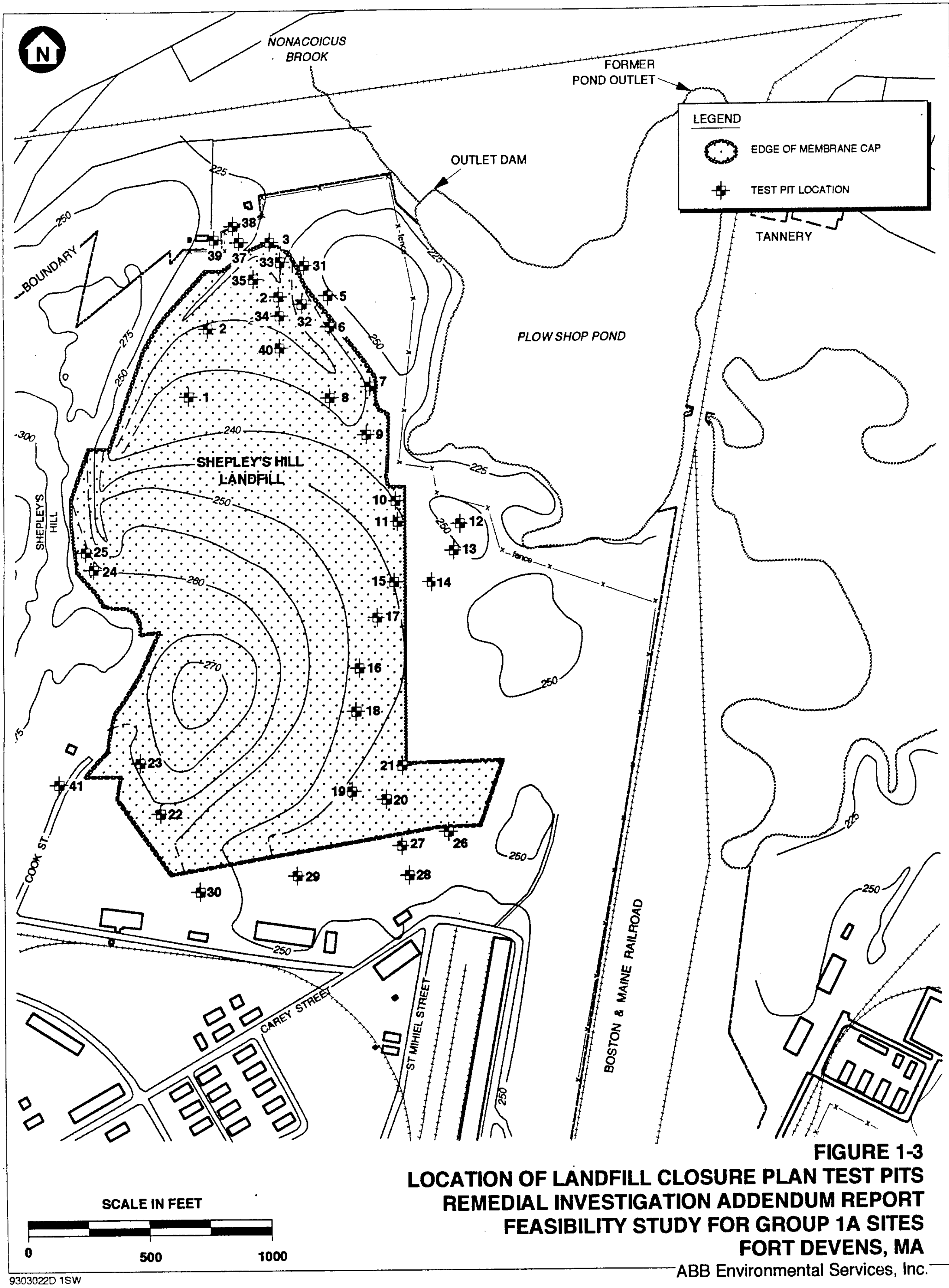

FIGURE 1-3
LOCATION OF LANDFILL CLOSURE PLAN TEST PITS
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

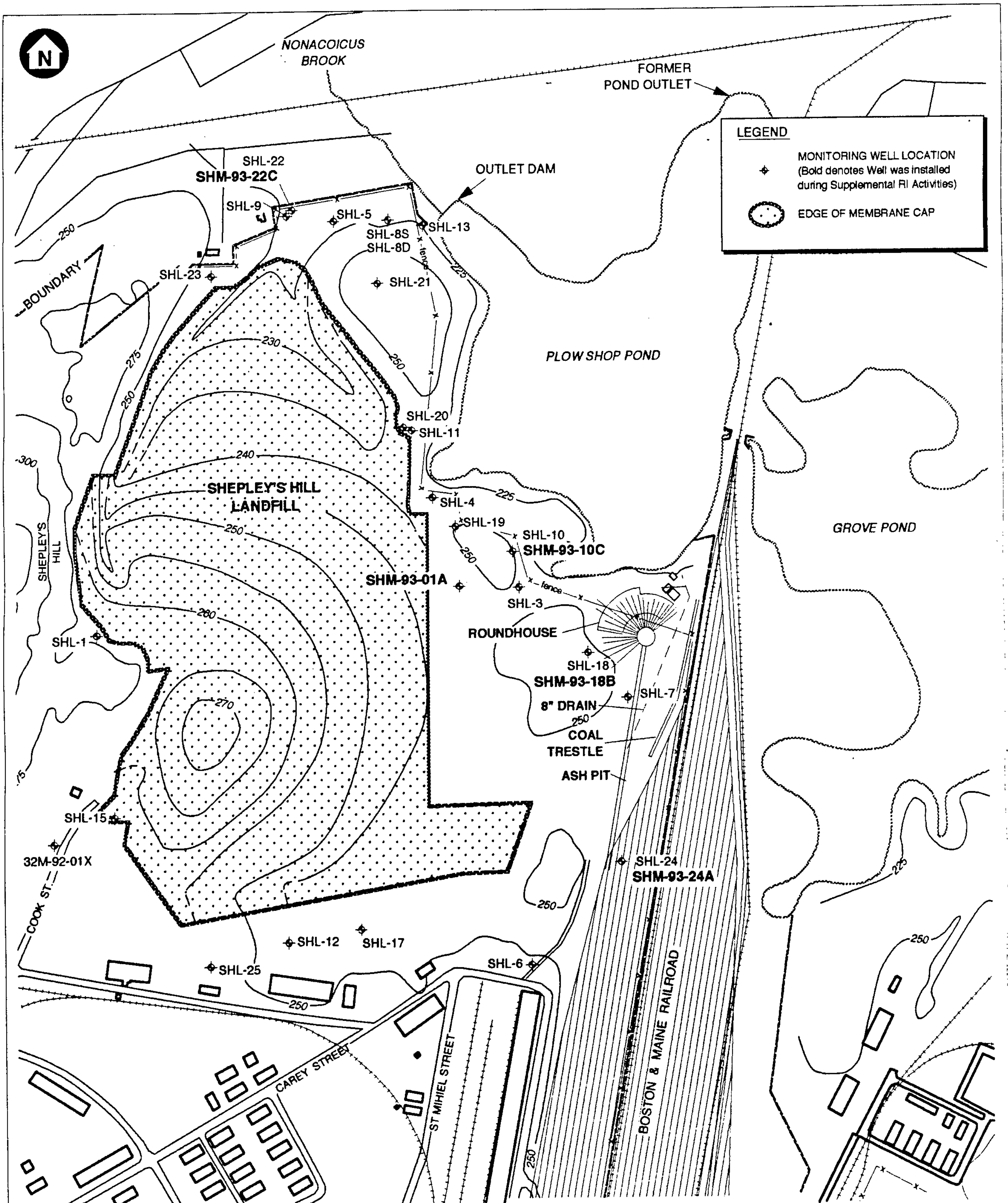

FIGURE 1-4
LOCATION OF FORMER RAILROAD ROUNDHOUSE FACILITY
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

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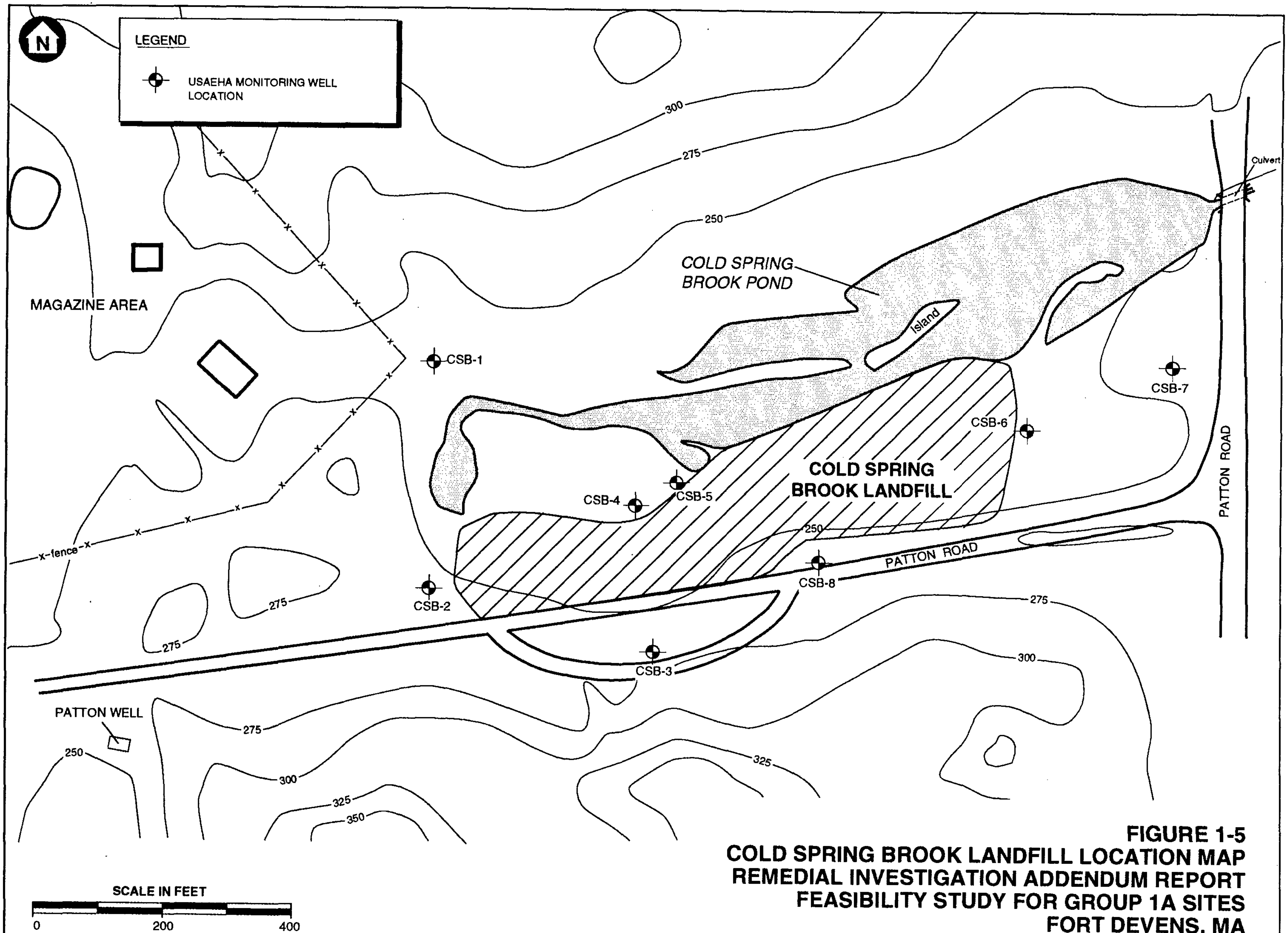

FIGURE 1-5
COLD SPRING BROOK LANDFILL LOCATION MAP
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

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TABLE 5-1
PROBABLE FATE AND TRANSPORT PATHWAYS FOR ORGANICS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHEMICAL	MW g/mole	WATER SOLUBILITY mg/L	SORPTION POTENTIAL Koc, mL/g	VAPOR PRESSURE mmHg	HENRY'S LAW CONSTANT atmxm^3/mol	BIODEGRADATION POTENTIAL	MEDIA WHERE DETECTED	PROBABLE FATE AND POTENTIAL TRANSPORT PATHWAYS
Volatiles								
1,1-Dichloroethane	99	$5.5x10^3$	30	$1.82x10^2$	$4.31x10^{-3}$	OM, RS	SHL GW	These volatile compounds are mobile in groundwater and volatile from soils and waters. They degrade under anaerobic conditions and more slowly under aerobic conditions. They can be expected in water systems and sediments.
1,2-Dichloroethane	99	$8.52x10^3$	14	$6.40x10^1$	$9.78x10^{-4}$	OM, RS	SHL GW	
1,1-Dichloroethylene	97	$2.25x10^3$	65	$6.0x10^2$	$3.40x10^{-2}$	OM, RM		
1,2-Dichloropropane	113	$2.70x10^3$	51	$4.2x10^1$	$2.31x10^{-3}$	OS, RN	SHL GW	
Chloroethane						OM, RM	SHL GW	
Chloroform	119	$8.2x10^3$	31	$1.51x10^2$	$2.87x10^{-3}$	OM, RM	SHL GW	
Trichloroethene	131	$1.1x10^3$	126	$5.79x10^1$	$9.10x10^{-3}$	OS, RS	SHL GW	
Tetrachloroethene	166	$1.50x10^2$	364	$1.78x10^1$	$2.59x10^{-2}$	OS, RN		
2-Butanone	72	$2.68x10^5$	.45	$7.75x10^1$	$2.74x10^{-0}$	OQ, RQ	CSBL SED	Very soluble in water and very biodegradable. Will transport in water.
Benzene	78	$1.75x10^3$	83	$9.52x10^1$	$5.59x10^{-3}$	OQ, RS	SHL GW	Soluble in water and volatile from waters and soils. Will transport with water systems. Very biodegradable in aerobic systems.
Semivolatiles								
Carbazole	167	insol	high	low	low	OS, RS	CSBL SED	Relatively insoluble in water, high sorption capability and low biodegradability. Expected preferentially in soils and sediments. Transport pathways primarily surface soil runoff and sedimentation.
Acenaphthylene	152	3.93	2500	$2.9x10^{-2}$	$1.48x10^{-3}$	OM, RM	CSBL SED	
Acenaphthene	154	3.42	4600	$1.55x10^{-3}$	$9.2x10^{-5}$	OS, RS	CSBL SED	
Anthracene	178	$4.5x10^{-2}$	$1.4x10^4$	$1.95x10^{-4}$	$1.02x10^{-3}$	OS, RS	CSBL SED	
Benzo(a)anthracene	228	$5.7x10^{-3}$	$1.38x10^6$	$2.2x10^{-8}$	$1.16x10^{-6}$	OS, RS	CSBL/SHL SED	
Benzo(a)pyrene	252	$1.2x10^{-3}$	$5.5x10^6$	$5.6x10^{-9}$	$1.55x10^{-6}$	OS, RS	CSBL SED	
Benzo(b)fluoranthene	252	$1.4x10^{-2}$	$5.5x10^5$	$5x10^{-7}$	$1.19x10^{-5}$	OS, RN	CSBL SED	
Benzo(g,h,i)perylene	276	$1.0x10^{-4}$	$1.6x10^6$	$1.03x10^{-10}$	$5.34x10^{-8}$	OS, RN		
Benzo(k)fluoranthene	252	$4.3x10^{-3}$	$5.5x10^5$	$5.1x10^{-7}$	$3.9x10^{-5}$		CSBL SED	
Bis-2(ethylhexyl)phthalate	391		$6.2x10^4$				CSBL GW & SED	
Chrysene	228	$1.8x10^{-3}$	$2.0x10^5$	$6.3x10^{-9}$	$1.05x10^{-6}$	OS, RN	SHL/CSBL SED	
Dibenzofuran						OM, RM	CSBL/SHL SED	
Fluoranthene	202	$2.06x10^{-1}$	$3.8x10^4$	$5.0x10^{-6}$	$6.46x10^{-6}$	OS, RN	CSBL/SHL SED	
Fluorene	116	1.69	$7.3x10^3$	$7.1x10^{-4}$	$6.42x10^{-5}$	OM, RS	CSBL SED	
Naphthalene						OQ, RS	CSBL/SHL SED	
Phenanthrene	178	$1.00x10^0$	$1.4x10^4$	$6.80x10^{-4}$	$1.59x10^{-4}$	OS, RS	CSBL/SHL SED	
Phenol	94	$9.30x10^4$	14	$3.41x10^{-1}$	$4.54x10^{-7}$	OQ, RM		
Pyrene	202	1.38	$3.8x10^4$	$2.5x10^{-6}$	$5.04x10^{-6}$	OS, RN	CSBL/SHL SED	
Pesticides/PCBs								
PPDDD	320	$1.0x10^{-1}$	$7.7x10^5$	$1.89x10^{-6}$	$7.96x10^{-6}$	ON, RS	CSBL/SHL SED	Relatively insoluble in water, high sorption capability and low biodegradability. Expected preferentially in soils and sediments. Transport pathways primarily surface soil runoff and sedimentation.
PPDDE	318	$4.0x10^{-2}$	$4.4x10^6$	$6.50x10^{-6}$	$6.80x10^{-5}$	ON, RS	CSBL/SHL SED	
PPDDT	355	$5.0x10^{-3}$	$2.43x10^5$	$5.5x10^{-6}$	$5.13x10^{-4}$	ON, RM	CSBL/SHL SED	

Notes:
M = moderate monthly
N = none/very slow
O = aerobic
Q = quick days
R = anaerobic
S = slow years

TABLE 5-2

PROBABLE FATE AND TRANSPORT PATHWAYS FOR INORGANICS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ELEMENT	PROBABLE SPECIES	POSSIBLE COMPOUNDS	WATER SOLUBILITY	VAPOR PRESSURE	SORPTION POTENTIAL	MEDIA WHERE DETECTED	PROBABLE FATE AND POTENTIAL TRANSPORT PATHWAYS
Al	Al(III)	$Al(OH)_3$	insol	negligible	strong	SHL GW,	Limited groundwater migration
As						SHL GW&SED CSBL GW&SED	As(V) coprecipitates and sorbs strongly. As(III) soluble in reducing waters. Biotransformation takes As(V) to As(III) and even As(−III). As(V) common on soils and in sediments. As(III) transported in groundwater, As(V) transported via surface water runoff and reduction to more mobile As(III) and As(−III).
	As(III)	H_3AsO_3 and salts	sol	negligible	strong		Groundwater migration of various arsenite salts
		$(CH_3)2AsO_2H$	sol	mod	low		Forms under microbial conditions.
		$(CH_3)AsO_3H_2$	sol				Volatilization and water transport.
				mod	low		
	As(V)	H_3AsO_4	sol	negligible	high		Sorbs to and precipitates on soils.
		AsO_4 salts	insol	negligible	high		Insoluble Ca, Ba, Al, Fe salts.
							Sorbs to or coprecipitates on soil with high iron and aluminum.
		As_2S_3	insol	negligible	strong		Forms under anaerobic conditions
	As(0)	As	insol				Forms under anaerobic conditions
	As(−III)	AsH_3	sol	high	low		Forms under very anaerobic conditions.
		$As(CH_3)_2$	sol	high	low		Forms under very anaerobic conditions.
Ba	Ba(II)					SHL GW&SED	
		$BaSO_4$	mod insol	negligible	med	CSBL SED	Transported via groundwater and surface water. Ba in
		$BaCO_3$	mod insol	negligible	med		soils transported via surface runoff. Present in both

TABLE 5-2
PROBABLE FATE AND TRANSPORT PATHWAYS FOR INORGANICS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ELEMENT	PROBABLE SPECIES	POSSIBLE COMPOUNDS	WATER SOLUBILITY	VAPOR PRESSURE	SORPTION POTENTIAL	MEDIA WHERE DETECTED	PROBABLE FATE AND POTENTIAL TRANSPORT PATHWAYS
		$Ba(OH)_2$	mod insol	negligible	med		soluble and insoluble forms.
Ca	Ca(II)	many salts	sol to insol	negligible	med to low	SHL GW CSBL GW	Present in soluble and insoluble forms. Transported with water and with soils by surface water runoff.
Mg	Mg(II)	many salts	sol to insol	negligible	med to low	SHL GW CSBL GW	
Cr						CSBL GW&SED SHL GW&SED	Cr(VI) and Cr(III) intraconvertible in most natural waters. Cr(VI) is stable under normal pH and oxidizing conditions, but at least part can be reduced by other elements present. Cr(III) is kinetically stable, and if present in the solid form, will persist. Cr(III) predominantly a solid. Cr(VI) predominantly soluble and transported with water.
	Cr(III)	Cr_2O_3 $Cr(OH)_2^+$	insol sol	negligible negligible	high high		Mostly solid form, can be oxidized slowly by MnO_2 even in soils. Coprecipitates with iron. Transported by surface runoff.
	Cr(VI)	CrO_4^{-2}	sol	negligible	low		Mostly soluble. Transported in waters. Can be reduced by organic matter.
Cu	Cu(I)	Cu_2O $Cu_2CO_3(OH)_2$ Cu_2S $Cu_2Fe_2O_4$, CuFeS	mod insol insol insol insol	negligible negligible negligible negligible	high high high high	CSBL GW&SED SHL GW&SED	Cu(I) under anaerobic conditions, Cu(II) under anae-robic conditions. Generally both forms are moderately soluble, but some individual salts and complex salts are insoluble. Primary transports pathways are groundwater surface water, sedimentation, and surface runoff.
	Cu(II)	CuO complexes	insol sol	negligible negligible	high low		Complexes limited by presence of Mg and Ca complexes.

TABLE 5-2
PROBABLE FATE AND TRANSPORT PATHWAYS FOR INORGANICS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ELEMENT	PROBABLE SPECIES	POSSIBLE COMPOUNDS	WATER SOLUBILITY	VAPOR PRESSURE	SORPTION POTENTIAL	MEDIA WHERE DETECTED	PROBABLE FATE AND POTENTIAL TRANSPORT PATHWAYS
		$CuFe_2O_4$	insol	negligible	high		
		$CuCO_3$	mod insol	negligible	high		
Fe	Fe(II)	$FeCO_3$	mod insol	negligible	high	SHL GW	Both Fe(II) and Fe(III) species are stable. Fe(II) predominates in a reducing environment and its salts are more soluble than Fe(III). Fe(III) primarily transported by surface water runoff. Fe(II) primarily transported in reduced waters.
		FeS	insol	negligible	high	CSBL SED	
		Fe^{+2}	sol	negligible	low		
	Fe(III)	$Fe(OH)_3$, Fe_3O_4	insol	negligible	high		
		FeS_2	insol	negligible	high		Present in reducing environments.
Hg	Hg(0)	Hg	insol	moderate	low	SHL SED	Volatilization and transformation of mercury into volatile forms is a primary pathway. Most mercury salts are soluble, but presence in water systems is controlled by complexation and insoluble HgS, Hg_2S, and $Hg(OH)_2$. Biological transformation of methylated mercury complicates the transport of mercury into soluble and volatile pathways. Transport pathways include water transport, volatilization, sedimentation, and with soils in surface water runoff.
	Hg(I)						
		Hg_2S	insol	negligible	high		
	Hg(II)	HgS	insol	negligible	high		
		$(CH_3)_2Hg$	low	high	low		
		$(CH_3)Hg^+$	high	low	low		
K	K(I)	K salts	high	negligible	low	SHL GW	Both Na and K are generally soluble and once in the water systems will be transported with the water. They are also present in minerals within the soils and sediments and will be transported in surface water runoff.
		K silicates and minerals				CSBL GW	
Na	Na(I)	Na salts	high	negligible	low	SHL GW	
		Na silicates and minerals				CSBL GW	
Mn	Mn(II)	Mn				CSBL GW&SED	Mn(II) is primarily soluble and Mn(IV) forms the very

TABLE 5–2
PROBABLE FATE AND TRANSPORT PATHWAYS FOR INORGANICS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ELEMENT	PROBABLE SPECIES	POSSIBLE COMPOUNDS	WATER SOLUBILITY	VAPOR PRESSURE	SORPTION POTENTIAL	MEDIA WHERE DETECTED	PROBABLE FATE AND POTENTIAL TRANSPORT PATHWAYS
		$MnCO_3$, Mn S,	mod sol	negligible	mod	SHL GW&SED	insoluble MnO_4. Under natural conditions, Mn(II) and
		$Mn(OH)_2$	mod sol	negligible	mod		Mn(IV) are intraconvertible. Transport of manganese
	Mn(IV)	MnO_2	insol	negligible	high		occurs with water, by sedimentation and with soil via
							surface water runoff.
Ni	Ni(II)	$NiCO_3$,	mod sol	negligible	mod	CSBL SED	Ni(II) is primarily soluble and mobile due to humic acid and
		$Ni(HCO_3)_2$	sol	negligible	mod	SHL GW&SED	carbonate complexes. Under reducing conditions NiS
		$NiFeO_4$	insol	negligible	high		forms and under aerobic conditions insoluble $NiFeO_4$ forms.
		$Ni(OH)^+$, Ni salts	sol	negligible	low		Transport in water systems, with sedimentation and with soil
		NiS	insol	negligible	high		in surface water runoff all occur.
Sb	Sb(III)	$Sb(OH)_3$	sol	negligible	mod	SHL GW	Antimony behaves much as As. Antimony occurs primarily as.
	Sb(V)	$Sb(OH)_6$	sol	negligible	mod		soluble oxides. Under reducing conditions, biomethylation
	Sb(–III)	SbH_3, $Sb(CH_3)_3$	mod sol	moderate	low		to volatile Sb compounds is possible but these oxidize in
							water to soluble oxides. Some insoluble salt formation with
							Fe, Mn and Al likely and limits transport in water systems.
							Transport in water systems, with sedimentation and with soil
							in surface water runoff all occur.
Se	Se(IV)	SeO_3^{-2}	insol/sol	negligible	high	SHL SED	Selenium behaves much as S and forms insoluble compounds
	Se(VI)	SeO_4^{-2}	insol/sol	negligible	high		and sorbs to ferric oxides or is reduced to the insoluble metal.
	Se(0)	Se	insol	negligible	high		Transport in water systems is limited primarily to sediment–
	Se(–II)	$(CH_3)_2Se$	insol	moderate	low		ation and surface water runoff with soil. Biomethylation and
							subsequent volatilization can occur in aquatic environments.
V	V(V)	VO_3^-	sol	negligible	low	SHL GW	Vanadium behavior in natural systems has not been well
	V(IV)	VO^{+2}	sol	negligible	low	CSBL GW	characterized. Soluble V(V) is the primary agent of transport

TABLE 5-2
PROBABLE FATE AND TRANSPORT PATHWAYS FOR INORGANICS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ELEMENT	PROBABLE SPECIES	POSSIBLE COMPOUNDS	WATER SOLUBILITY	VAPOR PRESSURE	SORPTION POTENTIAL	MEDIA WHERE DETECTED	PROBABLE FATE AND POTENTIAL TRANSPORT PATHWAYS
		$VO(OH)_2$	insol	negligible	high		in water. Sedimentation and surface water runoff may also occur.
Zn	Zn(II)	ZnS	insol	negligible	high	CSBL GW&SED	Zinc is moderately soluble under typical natural environmental
		$Zn(OH)_2$	sol	negligible	mod	SHL GW&SED	conditions. $ZnFe_2O_4$ may control solubility in water systems.
		Zn salts, $Zn(OH)^+$	sol	negligible	mod		Zn is coprecipitated with Fe and Mn oxides. Zinc will be trans-
		$Zn(HCO_3)_2$, $ZnCO_3$	sol	negligible	mod		ported in water systems, with sedimentation and surface water runoff.
Pb	Pb(II)	PbS	insol	negligible	strong	CSBL GW&SED	Pb(II) is generally soluble in natural water systems.
		$Pb(OH)^+$	sol	negligible	mod	SHL GW&SED	Precipitated lead can be mobilized via complexation
		$PbHCO_3^+$	sol	negligible	mod		and at high pHs. Lead sorbs strongly to soil and coprecip-
		$PbCO_3$	mod insol	negligible	strong		itates with oxides, Mn and Fe. Lead will be transported in
		$PbSO_4$	sol	negligible	strong		water systems, with sedimentation and surface water runoff.

6.0 HUMAN HEALTH RISK ASSESSMENT

The human health risk assessments presented here for Shepley's Hill Landfill and Cold Spring Brook Landfill are supplemental risk assessments that are based primarily on data presented in this RI Addendum Report. Baseline human health risk assessments were prepared by E&E during the initial RI. These risk assessments are included in the Remedial Investigations Report - Group 1A sites, Volumes I and II (April 1993) and will be referred to hereinafter as the RI Risk Assessments.

The Supplemental Risk Assessments presented here will include summaries of the RI Risk Assessments to provide a complete picture of the potential health risks associated with the two landfills. However, the reader should refer to the April 1993 Remedial Investigations Report for the detailed evaluations.

The following reports served as the primary guidance documents for the Supplemental Risk Assessments:

- Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final, December 1989

- Guidance for Disposal Site Risk Characterization and Related Phase II Activities - In Support of the Massachusetts Contingency Plan, May 17, 1989

6.1 SHEPLEY'S HILL LANDFILL

Data collected for this RI Addendum and used here in the Supplemental Risk Assessment for Shepley's Hill Landfill include fish tissue and sediment concentrations at Plow Shop Pond and new groundwater data (March and June 1993 sampling rounds) for Shepley's Hill Landfill. Subsection 2.1 of this report discusses the RI Addendum field investigation program and data gap activities at Shepley's Hill Landfill. A separate Preliminary Risk Evaluation (PRE) for Nonacoicus Brook Floodplain Area shallow groundwater and soil is provided in Appendix X. Subsection 4.1 is an evaluation of the nature and extent of contamination at Shepley's Hill Landfill.

Subsection 6.1.1 of the Supplemental Risk Assessment for Shepley's Hill Landfill contains a summary of the April 1993 RI Risk Assessment for the Landfill. Subsection 6.1.2 is the Supplemental Risk Assessment with its various subsections:

- Subsection 6.1.2.1 - Identification of Chemicals of Potential Concern (COPCs) and Estimation of Exposure Point Concentrations (EPCs)
- Subsection 6.1.2.2 - Exposure Assessment
- Subsection 6.1.2.3 - Toxicity Assessment
- Subsection 6.1.2.4 - Risk Characterization
- Subsection 6.1.2.5 - Comparison of Exposure Point Concentrations to Standards and/or Guidelines

Uncertainties typical to most risk assessments, including the RI Risk Assessment and the Supplemental Risk Assessment, were discussed in detail throughout the RI Risk Assessment. These will not be repeated here. Only those limitations or assumptions specific to the Supplemental Risk Assessment will be discussed in the appropriate sections of the Supplemental Risk Assessment.

Subsection 6.4.1 is a summary of the potential health risks associated with Shepley's Hill Landfill and Plow Shop Pond.

6.1.1 Summary of the RI Risk Assessment

In the RI Risk Assessment of April 1993, possible exposure pathways at Shepley's Hill Landfill were identified under existing site conditions and under an assumption that land surrounding the landfill would be converted to residential use in the future without any remediation.

Under current land use, the possible exposure pathways include the following:

- Incidental ingestion of surface water while fishing in Plow Shop Pond and consumption of fish caught in Plow Shop Pond by recreational fishermen and their families;

- Direct contact (dermal contact and incidental ingestion) with contaminated pond sediment along the landfill shoreline by site visitors; and

- Direct contact (dermal contact and incidental ingestion) with surface water by site visitors swimming in Plow Shop Pond.

Under an assumption of future residential use of the surrounding land, additional exposure pathways to those listed above were identified:

- Ingestion of contaminated groundwater as drinking water;

- Dermal contact with contaminated groundwater while bathing or showering, or through other household uses;

- Inhalation of contaminant vapors while bathing or showering, or through other household uses; and

- Consumption of homegrown fruits and vegetables watered with groundwater.

Summaries of the human health risks posed by exposure through these pathways are provided in Tables 6-1 and 6-2. The risk estimates reported in these tables were extracted from the RI Report and represent only those excess cancer risks above 1×10^{-6} and those hazard indices (HIs) above 1.0.

The USEPA Superfund Program uses these risk management guidelines as points of departure for determining remediation goals for NPL sites (USEPA, 1991i). This Superfund guidance for developing preliminary remediation goals also states that the use of "points of departure" target risks does not mean that final remedial actions should attain such goals. USEPA's guidelines state that when the total incremental carcinogenic risk for an individual resulting from exposure at a hazardous waste site is within the range of 10^{-4} to 10^{-6}, a decision about whether to take action or not is a site-specific decision. An USEPA Office of Solid Waste and Emergency Response (OSWER) directive, the "Role of Baseline Risk Assessment in Superfund Remedy Selection Decisions," indicates that action is generally warranted at a site when the cumulative carcinogenic risk is greater than

10^{-4} or the cumulative noncarcinogen'~ HI exceeds one, based on Reasonable Maximum Exposure (RME) assumptions (USEPA, 1991d).

Table 6-1 contains risk estimates for COPCs that the RI Report concluded were related to the landfill. Under current land use conditions, the ingestion of fish caught in Plow Shop Pond by recreational fishermen and their families presented health risks (both carcinogenic and noncarcinogenic) above the Superfund points of departure. In the RI Risk Assessment, the risks associated with fish ingestion were estimated by multiplying measured sediment concentrations by bioaccumulation factors; direct measurements of analyte concentrations in fish tissue had not been made at the time of the RI Risk Assessment. Fish tissue concentrations have been measured directly as part of the RI Addendum data gap activities. Arsenic and cadmium in the fish were responsible for most of the health risks. Incidental ingestion of pond water while fishing did not present health risks above the Superfund points of departure.

Under current land use conditions, direct contact with sediment along the western shoreline of Plow Shop Pond also presented health risks above the Superfund points of departure. Arsenic in the sediment was responsible for the health risk estimates above the points of departure. Although not quantitatively evaluated, the health risks from exposure to surface water by site visitors who swim in Plow Shop Pond were considered to be low.

Table 6-3 is a comparison of the average and maximum detected analyte concentrations in surface water to drinking water standards or guidelines. Surface water samples were collected and analyzed as part of the initial RI. Analyte concentrations were well below drinking water standards or guidelines, except for iron and manganese. The toxicity of iron to humans is relatively low, which is why no health-based drinking water standard exists for iron. Although the maximum detected concentration of manganese is above its Maximum Contaminant Level Goal (MCLG), the average concentration is below the MCLG. Ingestion of surface water while swimming provides for much less exposure potential than drinking water exposure, because of a lower volume being ingested and a less frequent exposure. Shoreline conditions at Plow Shop Pond discourage swimming (i.e., thick vegetation). Also, dermal absorption of waterborne inorganics is known to be very low. For these reasons, risks from ingestion and dermal contact with surface water while swimming in Plow Shop Pond are likely to be low and therefore are not evaluated further.

Under assumed future residential use of land surrounding the site, these same exposure pathways pose health risks above the points of departure. In addition, future ingestion of unfiltered groundwater as a drinking water source poses health risks above the points of departure. Most of the health risk was due to the presence of arsenic. Other chemicals in the groundwater including Aroclor-1260, beryllium, cadmium, manganese, heptachlor, and some VOCs, presented health risks above the points of departure but contributed a small percentage to the overall risk (see Table 6-1). Ingestion of groundwater as a drinking water source was responsible for most of the health risk (97 percent); direct contact with groundwater while bathing, the inhalation of VOCs in groundwater during showering, and the consumption of fruits and vegetables irrigated with groundwater contributed approximately 3 to 4 percent to the total risk.

Table 6-2 contains risk estimates for chemicals detected in media at Shepley's Hill Landfill that were assumed to be associated with sources other than the landfill. Under current land use conditions, the ingestion of two pesticides (heptachlor and DDE) and mercury assumed to be in Plow Shop Pond fish presented health risks above the Superfund points of departure. Estimated health risks from site visitor exposure to sediment along the eastern shoreline of Plow Shop Pond, where chemicals are not observed from the landfill, were below the points of departure.

Under assumed future residential use of land surrounding the site, the ingestion of fish containing chemicals originating from sources other than the landfill continued to present health risks above the points of departure. Visitor sediment contact along the eastern shoreline where chemicals are not derived from the landfill, presented health risks slightly above the point of departure for excess lifetime cancer risks, assuming more frequent contact under future use conditions than current land use conditions. Future residential use of groundwater from two well groupings containing chemicals from sources other than the landfill presented health risks above the points of departure.

Groundwater from well SHL-15, a well described in the RI Risk Assessment as upgradient from the landfill and outside of its zone of influence, contained several analytes posing health risks above the points of departure: arsenic, beryllium, dieldrin, manganese, and cadmium. Arsenic was responsible for most of the risk (see Table 6-2).

Another group of wells (SHL-7, -8, -8D, -13) considered in the RI Risk Assessment to be outside the landfill's zone of influence presented health risks above the Superfund points of departure. Arsenic (representing 98 percent of the total risk), beryllium, and manganese were responsible for most of the health risks.

The RI Risk Assessment also presented estimates of the health risks using groundwater data that were adjusted to account for the high suspended solids content of the unfiltered samples. These results are not reported here.

6.1.2 Supplemental Risk Assessment

As part of the data gap activities reported in this RI Addendum, filtered groundwater samples were collected and analyzed. All groundwater samples were analyzed for total metals and fifty percent of the samples were also analyzed for dissolved metals. The health risks associated with both unfiltered and filtered groundwater samples will be presented in this Supplemental Risk Assessment.

The objectives of the Supplemental Risk Assessment are the following:

- To assess the human health risks from potential exposure to landfill-related contaminants in groundwater, sediment, and fish tissue using primarily data reported in this RI Addendum.

- To present the total risks posed by the groundwater, sediment, and fish at Shepley's Hill Landfill, including landfill-related contaminants and chemicals thought to originate from sources other than the landfill.

- To compare the findings of the RI Risk Assessment with those of the Supplemental Risk Assessment.

- To identify those exposure pathways and contaminants that pose health risks above the Superfund points of departure for consideration in the FS.

- To identify uncertainties in the Risk Assessments that are important in making risk management decisions critical to the FS.

A summary of data collected as part of RI Addendum activities and used to identify COPCs for the Supplemental Risk Assessment follows.

6.1.2.1 Identification of COPCs and Estimation of EPCs. COPCs for the Supplemental Risk Assessment were identified primarily using data collected during RI Addendum data gap activities. These data include the latest groundwater sampling results from the March and June 1993 sampling rounds and fish tissue analyte concentrations from the October 1992 fish sampling program at Plow Shop Pond. Sediment COPCs were identified using both the RI and RI Addendum data sets. Subsection 2.1 describes these sampling programs in detail.

For the Supplemental Risk Assessment, COPCs are segregated into those considered landfill-related and those considered to originate from sources other than the landfill. The basis for segregating the COPCs in this way is provided in the contamination assessment in Subsection 4.1 and the hydrogeologic evaluation in Subsection 3.3.

Landfill-related COPCs in groundwater at Shepley's Hill Landfill were identified on the basis of monitoring well groupings. As in the RI Risk Assessment, monitoring wells were grouped into four groups for the Supplemental Risk Assessment. Table 6-4 lists the monitoring wells within these groups.

Based on the hydrogeologic investigation and the contaminant fate and transport analysis discussed in Subsections 3.3 and 5.1, some changes were made in the well groups between the RI Risk Assessment and this Supplemental Risk Assessment. Two wells formerly in Well Group 1 have been moved to Well Group 2 (background wells): SHL-12 and SHL-17. One well (SHL-7), formerly in Well Group 3, has also been moved to Well Group 2. Monitoring well SHL-21, formerly in Well Group 1, has been moved to Well Group 3.

Well Group 1 contains those monitoring wells interpreted to be downgradient of and within the zone of influence of Shepley's Hill Landfill. All COPCs within Well Group 1 are assumed to be landfill-related COPCs. Table 6-5 presents the summary statistics for the detected analytes in Well Group 1. Three detected analytes shown in Table 6-5 were not selected as COPCs - acetone, chloroform, and toluene. Acetone and toluene were both detected in only one of 14 samples at concentrations (15 and 0.56 μg/L, respectively) well below the Massachusetts drinking water standards/guidelines of 3,000 and 1,000 μg/L, respectively. The

presence of chloroform is attributed to blank contamination. Well Group 1 contains several VOCs and inorganic analytes. The maximum detected concentrations and arithmetic means serve as the Exposure Point Concentrations (EPCs) in the groundwater. Both unfiltered and filtered data are included in Table 6-5, and the Supplemental Risk Assessment will evaluate the health risks for both sets of data.

To calculate the arithmetic means presented in Tables 6-5 through 6-10, one-half the sample quantitation limit (SQL) was substituted for non-detects. Duplicate samples were averaged together and their average was used in the calculation of the mean. For the purpose of determining an analyte's frequency of detection, duplicate samples were averaged and counted as a single sample. If a maximum happened to be in a sample with a duplicate, the highest of the two samples was reported as the maximum, not an average of the two samples.

For groundwater, because the Round 2 data set is a subset of the Round 1 data set (that is, not all Round 1 wells were resampled in Round 2), the two rounds were averaged together; the averaged data points were used to calculate summary statistics (except maximums) for the well group. Maximum concentrations in groundwater were chosen from both sampling rounds before the two rounds were averaged together.

Summary statistics for Well Groups 3 and 4 are presented in Tables 6-6 and 6-7. Well Group 3 is a group of wells in the northeast corner of the landfill interpreted in the RI Addendum (Subsection 4.1) to be cross-gradient of the landfill and downgradient of Plow Shop Pond. Well Group 4 includes monitoring well SHL-15 and is evaluated separately here as was done in the RI Risk Assessment. During the RI, SHL-15 was expected to be an upgradient well but was interpreted to be contaminated.

No organic analytes were detected in Well Group 3. Only one organic analyte, trichlorofluoromethane, was detected in Well Group 4. Inorganic COPCs in Well Groups 3 and 4 include those analytes that were detected at concentrations above basewide background levels. An inorganic analyte was eliminated as a COPC only if its maximum detected concentration was below basewide background concentrations. Table 4-1 presents background concentrations of inorganic analytes in groundwater at Fort Devens.

Tables 6-8 and 6-9 present summary statistics on fish tissue concentrations at Plow Shop Pond. All detected analytes were included as COPCs. In the Supplemental Risk Assessment, the health risks associated with bluegills and with bullhead and bass caught in Plow Shop Pond are evaluated. Table 6-8 contains maximum and arithmetic mean concentrations of detected analytes in whole fish samples of bluegills. While USEPA risk assessment guidance (USEPA, 1989f) recommends performing risk assessments on edible tissue concentrations when available, bluegills (or sunfish) are small in size and could be expected to be cooked and eaten as whole fish. Of the analytes detected in the bluegills, arsenic, barium, iron, and manganese are assumed to be landfill-related. The remaining analytes are interpreted to be from sources other than the landfill.

Section 4.1 contains a discussion of those analytes in Plow Shop Pond sediment that are determined to be landfill-related and those that are not. For the purpose of selecting landfill-related COPCs in Plow Shop Pond fish, it was assumed that landfill-related COPCs in the fish are the same as those in pond sediment.

Table 6-9 contains maximum and arithmetic mean concentrations of detected analytes in the fillet portion (representing edible tissue) of bullheads and bass in Plow Shop Pond. Landfill-related COPCs in fish fillets include arsenic, iron, and manganese.

COPCs in Plow Shop Pond sediment were identified using the 13 sediment samples (SE-SHL-01 through SE-SHL-13) collected and analyzed for as part of the RI Report of April 1993 and the 28 sediment samples (SHD-92-01 through SHD-92-28) collected and analyzed for as part of this RI Addendum. The summary statistics presented in Table 6-10 for Plow Shop Pond sediment are based on these data; the maximum and arithmetic means in this table serve as the EPCs in this Supplemental Risk Assessment.

Four detected analytes were not selected as COPCs in sediment. Acetone and methylene chloride were considered to be laboratory contaminants in the RI Report. Heptachlor was a suspected laboratory contaminant in the RI Report and was not detected in any of the RI Addendum samples. Methyl ethyl ketone (or 2-butanone) was detected in 5 of 13 samples, but at a maximum concentration of only 0.13 ug/g. The RI Report questioned the presence of 2-butanone in organic-rich sediment in a warm water pond, and suspected it to be a laboratory

contaminant. For these reasons, 2-butanone was not selected as a COPC in sediment.

These EPCs are different from those used in the RI Risk Assessment. In the RI Risk Assessment, pond sediment samples were grouped into those representing contamination along the western shoreline and those representing the eastern shoreline. At a May 14, 1993 meeting with the regulatory agencies (USEPA Region I and MADEP Central Region) at Fort Devens, concern was expressed that this approach may underestimate actual shoreline concentrations. Maximum concentrations of some analytes were detected in the middle of the pond. The regulators postulated that if depositional areas along the shoreline were not fully characterized through sampling, and if sediment in the middle of the pond were to migrate to the shoreline, then actual shoreline concentrations could be higher than represented by the RI sampling results. Although ABB-ES believes that, based on the RI and RI Addendum sediment sampling program, actual sediment concentrations along the shorelines are probably well-characterized, a conservative approach as suggested by the regulatory agencies has been taken to select COPCs and estimate EPCs.

As discussed in Subsection 4.1, landfill-related COPCs in Plow Shop Pond sediment include arsenic, barium, iron, manganese, and nickel. While cadmium was considered a landfill-related COPC in the RI Risk Assessment, sediment sampling data collected and reported in this RI Addendum do not support that finding. Nickel was not considered a landfill-related COPC in the RI Risk Assessment but it is considered to be one in this report. Only inorganic analytes in the sediment are considered to be landfill-related in this Supplemental Risk Assessment. See Subsection 4.1 for more discussion on the nature and extent of contamination.

Table 6-11 contains a list of COPCs in groundwater, fish tissue, and sediment at Shepley's Hill Landfill and Plow Shop Pond. For fish tissue and sediment, landfill-related COPCs are shaded in the table. For groundwater, landfill-related COPCs are those in Well Group 1.

The analytical methods for inorganics used in the RI and the RI Addendum do not distinguish between oxidation states or the organic/inorganic form of a metal. For the Supplemental Risk Assessment, conservative or health-protective assumptions have been made in the evaluation of chromium and arsenic, two

metals whose toxicity varies significantly depending on chemical form and oxidation state.

Environmentally, chromium exists primarily as trivalent and hexavalent compounds. Hexavalent forms are considered to possess significantly more toxicity than the trivalent compounds because of the ease with which they are absorbed and distribute intracellularly (Goyer, 1991). Hexavalent chromium compounds are found to predominate in air, surface waters, and groundwaters, while the trivalent forms dominate in sediments and soils (USEPA, 1984b). Chromium in biological samples and foods exists almost exclusively in the trivalent state because of the rapid and complete intracellular reduction of absorbed hexavalent chromium to trivalent forms (Goyer, 1991). Because of these reasons, the following health-protective assumptions have been made in the evaluation of chromium:

- Chromium in groundwater is assumed to be in the hexavalent state.
- In sediment, even though the trivalent forms predominate, 10 percent of the chromium is assumed to exist as hexavalent compounds and 90 percent as trivalent forms.
- In fish tissue, all of the chromium is assumed to be trivalent.

The most common inorganic environmental arsenicals are trivalent arsenite compounds and pentavalent arsenate compounds. Trivalent forms are considered to possess two-to-three times the toxicity of pentavalent compounds. In food and biological samples, arsenic exists predominantly as organic arsenicals. Following absorption into biological species, inorganic arsenic compounds are rapidly and efficiently converted to organic forms. These metabolic pathways are considered detoxification pathways and the resultant organoarsenicals possess minimal inherent toxicity (Goyer, 1991 and USFDA, 1993). Bioconcentration of arsenic occurs in aquatic species. Specifically in fish, arsenobetaine, an organic arsenic compound, is the major form (99.9 to 59 percent) (Luten et al., 1982; ATSDR, 1992a). Arsenobetaine has been demonstrated to possess minimal inherent toxicity (LD50 >10 g/kg), undergoes no *in vivo* biotransformation, has tested negative for mutagenicity in *in vitro* screens, and is rapidly excreted (Kaise et al., 1985; Luten et al., 1982; Jongen et al., 1985). For the purposes of this report, all arsenic detected in groundwater, sediments, and fish samples is considered to be

trivalent inorganic arsenic. This assumption may result in risk calculations that are over-protective of health, especially in exposure pathways evaluating fish ingestion.

6.1.2.2 Exposure Assessment. In this exposure assessment, potential pathways of exposure are identified for Shepley's Hill Landfill under both current and future conditions of land and groundwater use. These exposure pathways were also evaluated in the RI Risk Assessment. However, in this Supplemental Risk Assessment, the most recent sampling data are used to estimate EPCs. The exposure parameter values and equations used to estimate chemical intakes are also presented. Any changes in exposure assumptions between the RI Exposure Assessment and this Supplemental Exposure Assessment will be reported here.

Under current land use, the potential exposure pathways evaluated include the following:

- Consumption of fish caught in Plow Shop Pond by recreational fishermen and their families.
- Direct contact (dermal contact and incidental ingestion) with sediment in Plow Shop Pond.

The RI Risk Assessment evaluated an additional exposure pathway whose health risks were found to be well below the Superfund points of departure. The excess lifetime cancer risks from the incidental ingestion of surface water in Plow Shop Pond while fishing were estimated to range from $4x10^{-8}$ to $1x10^{-7}$, considering both the average and RME cases and all COPCs (both site-related and from sources other than the landfill). HIs for noncarcinogenic effects ranged from 0.00002 to 0.001.

Because the health risks associated with this exposure pathway are well below the Superfund points of departure, and they would not significantly affect the calculation of total site risks, this exposure pathway has been eliminated from the Supplemental Risk Assessment.

Fort Devens is slated for closure. Therefore, future uses of the site and land surrounding the site may change. For this risk assessment, it is conservatively assumed that land surrounding the landfill could be converted to residential use in

the future, and private wells could be installed to provide drinking water for new homes in the area. Future use of the groundwater is unlikely because the base has an existing water supply, but cannot be ruled out. Under an assumption of future residential use of land surrounding the landfill, the following potential exposure pathways are identified:

- Ingestion of contaminated groundwater as drinking water.
- Dermal contact with contaminated groundwater while bathing or showering, or through other household uses.
- Inhalation of contaminant vapors while bathing or showering, or through other household uses.
- Consumption of homegrown fruits and vegetables watered with groundwater.

All these exposure pathways, in addition to those evaluated under conditions of current land use, were evaluated in the RI Risk Assessment. In this Supplemental Risk Assessment, the risks associated with the consumption of homegrown fruits and vegetables watered with groundwater were evaluated in Appendix Y.

Because the health risks associated with this pathway represent approximately 0.02 to 2 percent of the total risk from groundwater exposures, this pathway was not evaluated further in this Supplemental Risk Assessment. The results reported in Appendix Y are consistent with the risk estimates made for this exposure pathway in the RI Risk Assessment; in the RI Risk Assessment, as shown in Tables 8-26 through 8-32, the health risks associated with the consumption of produce irrigated with contaminated groundwater represented approximately 1 to 3 percent of the total risk from groundwater exposures. In addition, confidence in the risk estimates generated for the other three groundwater exposure pathways is much higher than for the irrigation pathway. The modeling of contaminant uptake and absorption by plants, and subsequent absorption by humans, introduces substantial uncertainty into the exposure assessment without affecting any conclusions regarding total site risk.

With few exceptions, the exposure parameter value assumptions made in the RI Risk Assessment are made in this Supplemental Risk Assessment. For the

groundwater exposure pathway, an area resident is assumed to consume COPCs in the groundwater (at 2 liters per day for 350 days per year) for a residential lifetime of 30 years (the national upperbound time [90th percentile] at one residence) at both average and maximum EPCs. This area resident is also assumed to contact COPCs in the groundwater during showering and to inhale any VOCs in the groundwater during showering. Because children represent a potentially sensitive subpopulation, the health risks to children from exposure to COPCs in the groundwater were also evaluated. A child was assumed to be exposed for a five-year period between the ages of one and six. Tables 6-12 and 6-13 contain the exposure parameter values for the groundwater exposure pathways.

Appendix K contains all of the spreadsheet tables (Tables K-1 through K-24) used to estimate health risks for the groundwater exposure pathway. Equations used to calculate COPC intakes are shown on the spreadsheets as well as all exposure parameter values with their references. Exposure parameter values used to estimate risks to adults are standard values prescribed in USEPA Risk Assessment Guidance (USEPA, 1989b; USEPA, 1989f; USEPA, 1991b). For children, appropriate exposure parameter values were taken from USEPA's Exposure Factors Handbook (USEPA, 1989b). Except for the use of a normalized surface area for a child, the exposure parameter values are the same as in the RI Risk Assessment.

Concentrations of VOCs in shower air volatilizing from groundwater were estimated using a model described in Appendix L. This same model was used in the RI Risk Assessment to model shower vapor concentrations. Appendix L also contains spreadsheets used to estimate VOC concentrations.

In the RI Risk Assessment, health risks from the consumption of fish in Plow Shop Pond were estimated by multiplying measured sediment concentrations by bioaccumulation factors. The lack of actual fish tissue concentrations was identified in the RI Report as a data gap. For this Supplemental Risk Assessment, measured fish tissue COPC concentrations were used to estimate COPC intakes. Tables K-25 through K-32 in Appendix K are the spreadsheets used to estimate COPC intakes from fish consumption. A recreational fisherman or family member is assumed to obtain 50 percent of his recreationally caught fish from Plow Shop Pond for a period of 30 years. He consumes these fish at the USEPA-prescribed ingestion rate for recreational fishing (54 grams/day or about

two 8-ounce servings per week; USEPA, 1991b). A child (age 1-6) is assumed to ingest fish at a rate of 16.5 grams/day (USEPA, 1989b). This assumption is different from the RI Risk Assessment which assumed the same ingestion rate as an adult. The lower ingestion rate can be justified based on smaller body size. Table 6-14 contains the exposure parameter values for the fish ingestion pathway.

For the sediment exposure pathway, an individual is assumed to contact the average and maximum detected concentrations of COPCs in sediment for 10 years. Under current land use, an adolescent is assumed to visit the pond once a week during the warmest six months of the year (26 days per year). Under assumed future land use conditions, an adolescent is assumed to visit the pond more frequently, at a rate of 100 days per year. Tables K-33 through K-40 in Appendix K are the spreadsheets used to estimate COPC intakes from sediment contact. Exposure parameter values are shown in Table 6-15. Except for the use of a normalized surface area, all values are the same as in the RI Risk Assessment.

In summary, EPCs for the three exposure pathways are provided in Tables 6-5 through 6-10. For groundwater, EPCs were calculated for the three well groups described in Subsection 6.1.2.1. Well Group 1 contains those monitoring wells interpreted to be downgradient of and within the zone of influence of Shepley's Hill Landfill. EPCs for Well Groups 3 and 4, not interpreted to be under the influence of the landfill, were calculated to allow estimation of total site risk. EPCs for fish tissue were calculated using the October 1992 sampling results for Plow Shop Pond. For sediment, as discussed in Subsection 6.1.2.1, EPCs were calculated using the 13 sediment samples collected and analyzed for as part of the RI Report and the 28 sediment samples collected and analyzed for as part of this RI Addendum.

The RI Risk Assessment estimated health risks under USEPA standard exposure assumptions as well as MADEP standard assumptions. For those exposure pathways evaluated in this Supplemental Risk Assessment, only minor differences were noted in the RI Risk Assessment between USEPA and MADEP exposure assumptions and attendant risk estimates. Tables 6-16 and 6-17 compare exposure assumptions and risk estimates. For both the sediment and fish ingestion pathways, USEPA risk estimates are higher than MADEP risk estimates. Only for the groundwater exposure pathway involving a child are USEPA's risk estimates slightly lower than MADEP's. As agreed upon with the regulatory

agencies during the May 14, 1993 meeting on risk assessment methodologies for the Supplemental Risk Assessment, only USEPA exposure assumptions and risk estimates will be produced here.

6.1.2.3 Toxicity Assessment. Tables 6-18 through 6-23 contain the dose/response values used to estimate excess lifetime cancer risks and noncarcinogenic health risks. Three sources were used to identify these values - USEPA's Integrated Risk Information System (IRIS), its Health Effects Assessment Summary Tables (HEAST), and values developed by the USEPA Environmental Criteria and Assessment Office (ECAO). Cancer slope factors and unit risks were identified for carcinogens and reference doses or concentrations were identified for noncarcinogens (compounds that exhibit threshold effects). Because the toxicity of a compound may vary depending on the route of exposure (for example, ingestion or inhalation), route-specific dose/response values were identified.

For carcinogens, Tables 6-18, 6-20, and 6-22 report both the quantitative measure of carcinogenic potency (i.e., the oral slope factor, the inhalation unit risk, and adjusted slope factor for the dermal route) and the USEPA's weight-of-evidence classification for the compound. USEPA has developed the following weight-of-evidence categories:

- Group A - Human Carcinogen: Sufficient evidence from epidemiological studies exists to support a causal association between an agent and human cancer.

- Group B - Probable Human Carcinogen: At least limited evidence exists from epidemiological studies of carcinogenicity in humans (Group B1) or, in the absence of human data, sufficient evidence of carcinogenicity exists in animals (Group B2).

- Group C - Possible Human Carcinogen: Limited evidence of carcinogenicity exists in animals in the absence of human data.

- Group D - Not Classified: The evidence for carcinogenicity in animals is inadequate.

- Group E - No Evidence of Carcinogenicity to Humans: Evidence of noncarcinogenicity in at least two adequate animal tests in different species or in both epidemiologic and animal studies exists.

For noncarcinogens, Tables 6-19, 6-21, and 6-23 report oral reference doses (RfDs), inhalation reference concentrations (RfCs), and adjusted RfDs for the dermal route of exposure, for COPCs at Shepley's Hill Landfill. RfDs and RfCs represent acceptable levels of exposure and include added margins of safety. USEPA defines an RfD as the average daily exposure level below which significant adverse noncarcinogenic health effects are not expected to occur, based on a lifetime of exposure. An RfC represents an acceptable concentration in air that a person may be exposed to 24 hours a day, every day for a lifetime, without experiencing an adverse effect.

Consistent with RAGs Appendix A (USEPA, 1989f), risks associated with calculated absorbed doses (most commonly for soil and water dermal contact) should be evaluated using RfDs and Cancer Slope Factors (CSFs) which are represented as absorbed doses. However, most oral RfDs and CSFs are based on administered dose rather than the absorbed dose. It is therefore necessary to adjust toxicity values which are based on administered dose so that they can be used for evaluation of absorbed doses. For dermal exposures, published oral reference doses were adjusted by multiplying the reference dose by the absorption efficiency in the study that is the basis of the oral toxicity value. Oral CSFs were adjusted by dividing the CSF by the absorption efficiency. If there was no information available on the absorption efficiency, the USEPA Region I default absorption fractions shown in Table 6-24 were used.

Because the toxicity of a noncarcinogen may vary depending on the duration of exposure, both chronic and subchronic RfDs and RfCs are reported. In the Supplemental Risk Assessment, the majority of the exposure scenarios involve chronic exposures (longer than seven years in duration, by USEPA definition). The only exposure scenarios involving subchronic exposures are those of a child ingesting groundwater and consuming fish for five years; subchronic dose/response values were used for these scenarios.

The RI Risk Assessment discusses uncertainties and limitations related to the methods of deriving dose/response values for use in human health risk assessment. These will not be repeated here. Only those limitations or

assumptions specific to the Supplemental Risk Assessment are discussed in the following paragraphs.

Arsenic is a COPC detected in groundwater, sediment, and fish tissue at Shepley's Hill Landfill at relatively high concentrations. Use of the cancer slope factor for arsenic to estimate excess lifetime cancer risks is thought by many to overestimate the true risk. The oral cancer slope factor for inorganic arsenic is based on dose/response data for skin cancer incidence obtained by Tseng et al. (1968). Individuals in this study were exposed to high levels of inorganic arsenic in drinking water (170 micrograms per milliliter [μg/ml]). Arsenic exposure was approximated based on estimates of water intake. Other exposure pathways contributing to total exposure, such as ingestion of fish, livestock, and plants were not assessed, potentially resulting in an underestimate of arsenic exposure. The oral slope factor was calculated using a model that assumes the dose/response curve is linear at low doses. Recent evidence suggests that arsenic, at low doses, may be largely detoxified by methylation, producing a non-linear dose/response curve (Goyer, 1991). In the study of Tseng et al. (1968), the overwhelming of the normal detoxification pathways, coupled with an underestimate of exposure, may have resulted in an overestimate of cancer risk.

The uncertainties summarized above have resulted in the USEPA IRIS file for inorganic arsenic reporting that, "The uncertainties associated with ingested inorganic arsenic are such that estimates could be modified downwards as much as an order of magnitude, relative to risk estimates associated with most other carcinogens" (IRIS, December 1993).

To consider the specific exposure scenario at Shepley's Hill Landfill, an additional factor becomes important to consider. As noted, arsenic in fish tissue exists largely as organic forms. These organic forms are known to possess minimal inherent toxicity and are believed to possess no mutagenic or carcinogenic potential (Kaise et al., 1985; Jongen et al., 1985). Therefore, cancer risk for this site may be significantly overestimated.

The noncancer risks associated with manganese in drinking water may also be overestimated in this risk assessment. The manganese drinking water RfD of 5.00E-03 mg/kg-day is based on a single epidemiological study conducted in Greece (Kondakis et al., 1989). Limitations with study design coupled with the lack of supporting studies may have resulted in a significant overestimate of the

risks associated with drinking water ingestion of manganese. The critical study assessed neurological function in an adequate number of individuals residing in three geographically distinct areas of Greece, each area with significantly different levels of manganese endemic to the local water supply. The study failed to investigate and quantitate other dietary sources of manganese in the study groups. The levels of manganese in locally grown produce and livestock can be presumed to reflect the local concentration of manganese in the water supply (i.e., the high manganese area would also have local food with higher levels of manganese than the areas with lower water levels). This study flaw may have resulted in the establishment of a drinking water RfD that is artificially low (i.e., overly protective). Additionally, the study assessed neurological function only in individuals older than 50 years of age. The neurological degeneration documented to be produced by high chronic manganese consumption is non-specific in nature and may in fact be produced by a number of other neurological diseases, such as Parkinson's Disease and Alzheimer's Disease, which increase in prevalence with age. The failure of this study to control for the presence of other neurological diseases or for patients with a family history of neurological disease lends uncertainty to the cause-and-effect relationship of manganese to the toxic endpoint assessed.

In addition to arsenic and manganese, other uncertainties or limitations exist in the use or lack of dose/response values for some COPCs at Shepley's Hill Landfill. These are summarized below:

- Two carcinogenic PAHs were detected in Plow Shop Pond sediment - benzo(a)anthracene and chrysene. Because they lack cancer slope factors, the slope factor for benzo(a)pyrene was used as a surrogate value. This is expected to overestimate the cancer risks from exposure to these PAHs because the potency of these two PAHs relative to benzo(a)pyrene is less, by factors of approximately 10 and 100, respectively (USEPA, 1992f; ICF-Clement Associates, 1987; Nisbet, I. and LaGoy, P., 1992).

- One VOC (1,2-dichloroethylene) detected in Well Group 1 groundwater monitoring wells does not have an inhalation RfC. This will produce an underestimation of the risks associated with the inhalation of VOCs in groundwater.

- Benzene, chloroethane, 1,2-dichloropropane, and 1,2-dichloroethane do not have oral RfDs. This will result in an underestimate of the risks associated with groundwater ingestion. However, for benzene and 1,2-dichloropropane, they are evaluated quantitatively as carcinogens; their cancer risks would be expected to dominate the noncarcinogenic risks.

- Several inorganic analytes could not be evaluated quantitatively because of a lack of dose/response values. These include aluminum, calcium, cobalt, copper, iron, lead, magnesium, potassium, and sodium. Except for lead, this would not be expected to change the results of the risk assessment significantly. These analytes are common nutrients or essential nutrients with relatively low toxicities. The omission of lead from the quantitative assessment will result in an underestimate of the risks associated with groundwater ingestion, sediment contact, and fish ingestion.

Table 6-24 contains default absorption fractions used in the estimation of COPC intake. At the direction of USEPA Region I, default absorption fractions are taken from the Region I Supplemental Risk Assessment Guidance Document (USEPA, 1989c). These absorption fractions are used in this assessment. Following USEPA Region I guidance, the agency's guidance document entitled "Dermal Exposure Assessment: Principles and Applications", Interim Report, January 1992 (USEPA, 1992d) has been followed in assessing the health risks associated with dermal contact with COPCs. Appendix V contains a description of how information provided in the dermal guidance document is used in this Supplemental Risk Assessment. Appendix W contains spreadsheets used to estimate permeability constants per event, a composite variable representing several of the variables discussed in Appendix V.

6.1.2.4 Risk Characterization. In this risk characterization, risk estimates are produced by combining COPC intakes estimated in the Exposure Assessment and dose/response values in the Toxicity Assessment. These risk estimates are compared to the USEPA points of departure identified in Subsection 6.1.1. In addition, the method for estimating both excess lifetime cancer risks as well as possible noncarcinogenic adverse effects is described.

Excess lifetime cancer risk is calculated by multiplying the COPC intake (in units of mg/kg/day) by a compound's cancer slope factor (in units of $(mg/kg/day)^{-1}$). The cancer slope factors in IRIS are typically upper 95th percent confidence limits on the probability of a tumor response based on experimental data. Therefore, the cancer risk limits presented here and in the RI Risk Assessment are considered to be upperbound estimates of risk. The "true risk" to an individual is likely to be much lower (USEPA, 1989f).

Noncarcinogenic risk estimates are calculated by dividing exposure intakes for each noncarcinogen by the appropriate reference dose. The resulting ratio is termed a Hazard Quotient (HQ). The sum of the HQs for individual compounds within an exposure pathway is called the HI. If an HI is less than or equal to one, no adverse health effects are anticipated from exposure at the predicted intake level. If the ratio is greater than one, the predicted intake could potentially cause adverse health effects. This determination is necessarily imprecise because the derivation of dose/response values (i.e., RfDs and RfCs) involves the use of multiple safety and uncertainty factors. In addition, the HQs for individual compounds should properly be summed only if their target organs or mechanisms of action are identical. Therefore, the potential for adverse effects for a mixture having an HI in excess of one must be assessed on a case-by-case basis.

Tables 6-25 and 6-26 are summaries of the cancer and noncancer risk estimates for Shepley's Hill Landfill under conditions of current land use. Excess lifetime cancer risks associated with the ingestion of fish from Plow Shop Pond and visitor contact with sediment exceed the USEPA point of departure of $1x10^{-6}$ for carcinogens. The risks faced by a trespasser contacting sediment in Plow Shop Pond under an assumed frequency of 26 days per year for 10 years range from $2x10^{-5}$ to $2x10^{-4}$ for mean and maximum exposure point concentrations. Arsenic, a landfill-related COPC, is responsible for essentially 100 percent of the risk. The risks faced by a recreational fisherman or member of his family who consumes fish from Plow Shop Pond range from $3x10^{-6}$ to $4x10^{-4}$; the fisherman is assumed to ingest fish at the USEPA-prescribed ingestion rate of 54 grams per day (or two 8-ounce servings per week) and to obtain half his recreationally caught fish from Plow Shop Pond. Arsenic in the fish accounts for approximately 96 to 99 percent of the risk. An additional COPC, DDE, presents risks above the USEPA point of departure (at $2x10^{-6}$); this COPC is not thought to be landfill-related and represents 0.4 to 4 percent of the total risk from fish ingestion.

An additional COPC in Plow Shop Pond fish, mercury, presents noncancer risks above the USEPA point of departure. The HQ associated with mercury in bullhead and bass ranges from 2 to 7. Mercury is not thought to be landfill-related. Although arsenic is responsible for most of the health risk in bluegills in Plow Shop Pond, the HQ for three other COPCs approach one at maximum EPCs (manganese, 0.3; mercury, 0.9; and, thallium, 0.7).

Total site risks were calculated in Tables 6-25 and 6-26 to estimate the health risks that a receptor might face who could potentially be exposed by more than one exposure pathway. Under current land use conditions at Shepley's Hill Landfill, an adult was assumed to ingest fillets from Plow Shop Pond for 30 years and contact the sediment for 10 of these 30 years (as an adolescent). The excess lifetime cancer risks for this receptor range from $3x10^{-5}$ to $2x10^{-4}$. The total site cancer risks for a child (age 1-6) were assumed to come from the ingestion of fillets, and range from $3x10^{-6}$ to $9x10^{-6}$ for landfill-related COPCs. Because it is inappropriate to add hazard indices across different age groups (acceptable doses or reference doses being body weight- or age-dependent), hazard indices for the adult, adolescent, and child receptors were not added together. The noncancer risks for the three age groups are as reported above and are independent of each other.

Tables 6-27 and 6-28 are summaries of the cancer and noncancer risk estimates under the assumption of future residential use of land surrounding the landfill. Because the exposure assumptions for fish ingestion are the same under conditions of current and future land use, the risks are the same. Under future land use conditions, the frequency of sediment contact is assumed to be greater than under current conditions. Therefore, the health risks under future conditions are predicted to be slightly higher than under current conditions. Arsenic in the sediment is responsible for the majority of the risk.

Under the assumption of future residential use of land surrounding the landfill, the total site cancer risks for a receptor exposed concurrently (for 30 years) to COPCs in unfiltered groundwater and Plow Shop Pond fish and sediment range from $5x10^{-4}$ to $3x10^{-3}$ for mean and maximum EPCs, respectively. The total site cancer risks for a child (age 1-6) were assumed to come from the ingestion of fillets and unfiltered groundwater exposure, and range from $8x10^{-5}$ to $3x10^{-4}$. Total site noncancer risks were calculated within the three receptor groups. For

an adult or child exposed to landfill-related COPCs in fillets and in unfiltered groundwater, the total hazard index ranges from 5 to 20.

The use of groundwater from Well Group 1 (those wells under the influence of the landfill) for domestic purposes also poses risks above the points of departure. The cancer risks associated with groundwater consumption range from $8x10^{-5}$ to $2x10^{-3}$. Arsenic accounts for about 99 percent of the total risk. Two organic compounds, 1,2-dichloroethane and dichlorobenzenes, also present risks above the point of departure, at $3x10^{-6}$; however, they account for less than 1 percent of the total risk. The HQs for manganese exceed 1; they range from 2 to 16.

A summary of the health risks associated with the residential use of groundwater from Well Groups 3 and 4 is provided in Table 6-29. Well Groups 3 and 4 are not interpreted to be under the influence of Shepley's Hill Landfill.

6.1.2.5 Comparison of EPCs to Standards and Guidelines. The U.S. Food and Drug Administration (FDA) issues action levels for contaminants in fish (USFDA, 1992). Action levels are established by the FDA to control levels of contaminants in human food and animal feed. They represent limits at or above which the FDA will take legal action to remove products from the market. The FDA has issued action levels for three of the COPCs detected in either the bluegills, bullhead, or bass evaluated in this Supplemental Risk Assessment. Table 6-30 contains these action levels. Detected concentrations of mercury in the bullhead and bass fillets in Plow Shop Pond exceed the FDA action level for mercury of 1 part per million (ppm). The average and maximum concentrations of mercury detected were 1.14 and 4 ppm, respectively. The maximum detected concentration of DDE in the fish at Plow Shop Pond is below its respective FDA action level.

Tables 6-31 through 6-33 contain drinking water and groundwater standards and guidelines for COPCs detected in groundwater at Shepley's Hill Landfill. Average and maximum detected concentrations of COPCs are provided as well. For Well Group 1, the maximum detected concentrations of several analytes in unfiltered groundwater exceed a primary (or health-based) federal or state drinking water standard (see Table 6-31). These include: 1,2-dichloroethane, dichlorobenzenes, arsenic, chromium, lead, and nickel. Based on filtered samples, however, the maximum concentration of lead is below the federal action level for lead. Neither chromium nor nickel were detected in filtered samples. Manganese was detected

at concentrations above its proposed federal MCL. Dichlorobenzenes (isomers unidentified) were detected in one of 14 samples; while the maximum exceeds the state drinking water guideline for p-dichlorobenzene (the isomer with the lowest guideline), the average (5.4 μg/L) approximates the guideline (5 μg/L). While the maximum detected concentration of 1,2-dichloroethane (9.9 μg/L) exceeds the federal MCL of 5 μg/L, the average concentration of 0.97 μg/L does not exceed the MCL. Secondary Maximum Contaminant Levels (SMCLs), standards developed to protect against unacceptable aesthetic effects (such as appliance or clothes staining or taste) are exceeded for aluminum, iron, and manganese. The federal and state guidelines for sodium in drinking water were also exceeded. Sodium guidelines have been set for people on sodium-restricted diets.

Comparisons of groundwater EPCs at Well Groups 3 and 4 are provided in Tables 6-32 and 6-33. At Well Group 3, the concentrations of aluminum, iron, and manganese exceed standards or guidelines. At Well Group 4, the concentrations of aluminum, iron, and manganese exceed standards or guidelines.

6.2 Cold Spring Brook Landfill

Data collected for this RI Addendum and used here in the Supplemental Risk Assessment for Cold Spring Brook Landfill include fish tissue and sediment concentrations at Cold Spring Brook Pond and new groundwater data (March and June 1993 sampling rounds) for Cold Spring Brook Landfill. Subsection 2.2 of this report discusses the RI Addendum field investigation program and data gap activities at Cold Spring Brook Landfill. Subsection 4.5 is an evaluation of the nature and extent of contamination at Cold Spring Brook Landfill.

Subsection 6.2.1 of the Supplemental Risk Assessment for Cold Spring Brook Landfill contains a summary of the April 1993 RI Risk Assessment for the Landfill. Subsection 6.2.2 is the Supplemental Risk Assessment with its various subsections.

- Subsection 6.2.2.1 - Identification of COPCs and Estimation of EPCs
- Subsection 6.2.2.2 - Exposure Assessment

- Subsection 6.2.2.3 - Toxicity Assessment
- Subsection 6.2.2.4 - Risk Characterization
- Subsection 6.2.2.5 - Comparison of Exposure Point to Standards and/or Guidelines

Uncertainties typical to most risk assessments, including the RI Risk Assessment and the Supplemental Risk Assessment, were discussed in detail throughout the RI Risk Assessment. These will not be repeated here. Only those limitations or assumptions specific to the Supplemental Risk Assessment will be discussed in the appropriate sections of the Supplemental Risk Assessment.

Subsection 6.4.2 is a summary of the potential health risks associated with Cold Spring Brook Landfill and Cold Spring Brook Pond.

6.2.1 Summary of the RI Risk Assessment

In the RI Risk Assessment of April 1993, possible exposure pathways at Cold Spring Brook Landfill were identified under existing site conditions and under an assumption that land surrounding the landfill would be converted to residential use in the future without any remediation.

Under current land use, the possible exposure pathways include the following:

- Incidental ingestion of surface water while fishing in Cold Spring Brook Pond and consumption of fish caught in Cold Spring Brook Pond by recreational fishermen and their families;
- Direct contact (dermal contact and incidental ingestion) with contaminated pond sediment along the landfill shoreline by site visitors; and
- Direct contact (dermal contact and incidental ingestion) with contaminated surface soil at the landfill by site visitors.

Under an assumption of future residential use of surrounding land, additional exposure pathways to those listed above were identified:

- Ingestion of contaminated groundwater as drinking water;
- Dermal contact with contaminated groundwater while bathing or showering, or through other household uses;
- Consumption of homegrown fruits and vegetables watered with groundwater.

A summary of the human health risks posed by exposure through these pathways is provided in Table 6-34. The risk estimates reported in this table were extracted from the RI Report and represent only those excess cancer risks above $1x10^{-6}$ and those HIs above one.

The USEPA Superfund Program uses these risk management guidelines as points of departure for determining remediation goals for NPL sites (USEPA, 1991i). This Superfund guidance for developing preliminary remediation goals also states that the use of "points of departure" target risks does not mean that final remedial actions should attain such goals. USEPA's guidelines state that when the total incremental carcinogenic risk for an individual resulting from exposure at a hazardous waste site is within the range of 10^{-4} to 10^{-6}, a decision about whether to take action or not is a site-specific decision. An OSWER directive, the "Role of Baseline Risk Assessment in Superfund Remedy Selection Decisions," indicates that action is generally warranted at a site when the cumulative carcinogenic risk is greater than 10^{-4} or the cumulative noncarcinogenic HI exceeds one, based on RME assumptions (USEPA, 1991d).

Under current land use conditions, the ingestion of fish caught in Cold Spring Brook Pond by recreational fishermen and their families presented excess lifetime cancer risks above the Superfund point of departure. In the RI Risk Assessment, the risks associated with fish ingestion were estimated by multiplying measured sediment concentrations by bioaccumulation factors; direct measurements of analyte concentrations in fish tissue had not been made at the time of the RI Risk Assessment. Fish tissue concentrations have been measured directly as part of the RI Addendum data gap activities. Arsenic, DDD, and DDE in the fish were responsible for most of the health risks. Incidental ingestion of pond water while fishing did not present health risks above the Superfund points of departure.

Although not evaluated as a potential exposure pathway in the RI Risk Assessment, the health risks from contact with Cold Spring Brook Pond surface water while swimming are expected to be low. Table 6-35 is a comparison of the average and maximum detected analyte concentrations in surface water to drinking water standards and guidelines. Except for iron and manganese, the detected concentrations are below drinking water standards. Iron has a relatively low toxicity for humans, and the average concentration of manganese is below its MCLG. Based on the above comparisons and the existence of conditions at Cold Spring Brook Pond that discourage swimming, health risks are expected to be low and will not be evaluated further.

Under current land use conditions, direct contact with sediment along the shoreline of Cold Spring Brook Pond also presented excess lifetime cancer risks (only at maximum detected concentrations) above the Superfund point of departure. Arsenic and PAHs in the sediment were responsible for the health risk estimates above the point of departure. Direct contact with surface soil at the landfill did not pose health risks in excess of the points of departure.

Under assumed future residential use of land surrounding the site, these same exposure pathways pose health risks above the points of departure. For the fish ingestion pathway, in addition to arsenic, DDD, and DDE, zinc posed a noncarcinogenic risk above the point of departure of one; this was due to the assumption that, in the future, 50 percent of an individual's recreationally caught fish would come from Cold Spring Brook Pond as opposed to 5 percent under current conditions. Contact with surface soil by area residents in the future presented excess lifetime cancer risks above the Superfund point of departure due to PAHs in the soil.

In addition, future ingestion of unfiltered groundwater as a drinking water source posed health risks above the points of departure. The majority of the health risk was due to the presence of arsenic. Other chemicals in the groundwater, beryllium and manganese, presented health risks above the points of departure but contributed a small percentage to the overall risk (see Table 6-34). Ingestion of groundwater as a drinking water source was responsible for most of the health risk (97 percent); direct contact with groundwater while bathing and the consumption of fruits and vegetables irrigated with groundwater contributed approximately 1 to 4 percent to the total risk.

The RI Risk Assessment also presented estimates of the health risks using groundwater data that were adjusted to account for the high suspended solids content of the unfiltered samples. These results are not reported here.

6.2.2 Supplemental Risk Assessment

As part of the data gap activities in this RI Addendum, filtered groundwater samples were collected and analyzed. The health risks associated with both unfiltered and filtered groundwater samples will be presented in this Supplemental Risk Assessment.

The objectives of the Supplemental Risk Assessment are the following:

- To assess the human health risks from potential exposure to landfill-related contaminants in groundwater, sediment, and fish tissue primarily using data reported in this RI Addendum.
- To compare the findings of the RI Risk Assessment with those of the Supplemental Risk Assessment.
- To identify those exposure pathways and contaminants that pose health risks above the Superfund points of departure for consideration in the FS.
- To identify uncertainties in the Risk Assessments that are important in making risk management decisions critical to the FS.

A summary of data collected as part of RI Addendum activities and used to identify COPCs for the Supplemental Risk Assessment follows.

6.2.2.1 Identification of COPCs and Estimation of EPCs. COPCs for the Supplemental Risk Assessment were identified primarily using data collected during RI Addendum data gap activities. These data include the latest groundwater sampling results from the March and June 1993 sampling rounds and fish tissue analyte concentrations from the October 1992 fish sampling program at Cold Spring Brook Pond. Sediment COPCs were identified using the RI and RI Addendum data sets. Subsection 2.2 describes both sampling programs in detail.

COPCs in groundwater at Cold Spring Brook Landfill were identified on the basis of monitoring well groupings. In the RI Risk Assessment, monitoring wells were grouped into three groups. The first group included wells located within the landfill's zone of influence, the second group included wells interpreted to be outside the landfill's zone of influence, and the third group was the Patton well. The Patton well, one of four water supply wells for Fort Devens, is located approximately 600 feet from the southwestern corner of the landfill. Groundwater exposures were evaluated only for the set of wells within the landfill's zone of influence.

Some changes were made in the first two well groups between the RI Risk Assessment and this Supplemental Risk Assessment. Monitoring data from three new wells installed as part of the RI Addendum (CSM-93-01A, -02A, and -02B) were added to the group of wells considered within the landfill's zone of influence. Wells CSB-3 through CSB-8, formerly included in the set of landfill-influenced wells, have been removed for the Supplemental Risk Assessment. This decision is based on the findings of the hydrogeologic investigation and the contaminant assessment discussed in Subsection 4.4 of this report. CSB-3 and CSB-6 through CSB-8 have been interpreted to be either upgradient or cross-gradient of Cold Spring Brook Landfill. As agreed at the May 14, 1993 risk assessment meeting at Fort Devens, CSB-4 and CSB-5 have been excluded because these wells are not considered to be representative of a productive aquifer. For the Supplemental Risk Assessment, the group of wells at Cold Spring Brook Landfill considered within the landfill's zone of influence are referred to as the "downgradient wells."

Table 6-36 presents the RI Addendum summary statistics for the detected analytes in the downgradient wells. One organic compound, bis(2-ethylhexyl)phthalate, and several inorganic analytes were detected. The maximum detected concentrations and arithmetic means serve as the EPCs in the groundwater. Both unfiltered and filtered data are included in Table 6-36, and the Supplemental Risk Assessment will evaluate the health risks for both sets of data.

To calculate the arithmetic means presented in Table 6-36, one-half the SQL was substituted in for non-detects. Duplicate samples were averaged together and their average was used in the calculation of the mean. For the purpose of determining an analyte's frequency of detection, duplicate samples were averaged and counted as a single sample. The Round 1 and 2 data sets were averaged

together and the averaged concentrations were then used to calculate summary statistics (except maximums). The maximum was chosen from both rounds before they were averaged. If a maximum happened to be in a sample with a duplicate, the highest of the two samples was reported as the maximum, not an average of the two samples.

COPCs in the downgradient wells include those inorganic analytes that were detected at concentrations above basewide background levels. An inorganic analyte was eliminated as a COPC only if its maximum detected concentration was below basewide background. Table 4-1 presents background concentrations of inorganic analytes in groundwater at Fort Devens.

Tables 6-37 and 6-38 present summary statistics on fish tissue concentrations at Cold Spring Brook Pond. In the Supplemental Risk Assessment, the health risks associated with pumpkinseeds and with bullhead and pickerel caught in Cold Spring Brook Pond are evaluated. Table 6-37 contains maximum and arithmetic mean concentrations of detected analytes in whole fish samples of pumpkinseeds. While USEPA risk assessment guidance (USEPA, 1989f) recommends performing risk assessments on edible tissue concentrations when available, pumpkinseeds are small in size and could be expected to be cooked and eaten as whole fish. Table 6-38 contains maximum and arithmetic mean concentrations of detected analytes in the fillet portion (representing edible tissue) of bullheads and pickerel in Cold Spring Brook Pond.

COPCs in Cold Spring Brook Pond sediment were identified using the nine sediment samples (SE-CSB-01 through SE-CSB-09) collected and analyzed for as part of the RI Report of April 1993 and the 16 sediment samples (CSD-92-01 through CSD-92-16) collected and analyzed for as part of this RI Addendum. The summary statistics presented in Table 6-39 for Cold Spring Brook Pond sediment are based on these data; the maximum and arithmetic means in this table serve as the EPCs in this Supplemental Risk Assessment. All detected analytes (except acetone, methylene chloride, and 2-butanone) in sediment were considered COPCs for the Supplemental Risk Assessment. Acetone and methylene chloride were considered laboratory contaminants in the RI Report. 2-Butanone was detected in only one of 9 samples at a low concentration (0.025 ug/g). This is different from the RI Risk Assessment. In the RI Risk Assessment, only analytes whose detected concentrations exceeded their upper tolerance limits for Fort Devens soil were selected as COPCs.

Table 6-40 contains a list of COPCs in groundwater, fish tissue, and sediment at Cold Spring Brook Landfill and Cold Spring Brook Pond. For groundwater, COPCs are those chemicals detected in the downgradient wells.

The analytical methods for inorganics used in the RI and the RI Addendum do not distinguish between oxidation states or the organic/inorganic form of a metal. For the Supplemental Risk Assessment, conservative or health-protective assumptions have been made in the evaluation of chromium and arsenic, two metals whose toxicity varies significantly depending on chemical form and oxidation state.

6.2.2.2 Exposure Assessment. In this exposure assessment, potential pathways of exposure are identified for the Cold Spring Brook Landfill under both current and future conditions of land and groundwater use. These exposure pathways were also evaluated in the RI Risk Assessment. However, in this Supplemental Risk Assessment, the most recent sampling data are used to estimate EPCs. The exposure parameter values and equations used to estimate chemical intakes are also presented. Any changes in exposure assumptions between the RI Exposure Assessment and this Supplemental Exposure Assessment will be reported here.

Under current land use, the potential exposure pathways evaluated include the following:

- Consumption of fish caught in Cold Spring Brook Pond by recreational fishermen and their families.
- Direct contact (dermal contact and incidental ingestion) with sediment in Cold Spring Brook Pond.

An additional exposure pathway was evaluated in the RI Risk Assessment whose health risks were found to be well below the Superfund points of departure. The excess lifetime cancer risks from the incidental ingestion of surface water in Cold Spring Brook Pond while fishing were estimated to range from 3×10^{-8} to 3×10^{-7}, considering both the average and RME cases. HIs for noncarcinogenic effects ranged from 0.00005 to 0.005. Because the health risks associated with this exposure pathway are well below the Superfund points of departure, and they would not significantly affect the calculation of total site risks, this exposure pathway has been eliminated from the Supplemental Risk Assessment.

Fort Devens is slated for closure. Therefore, future uses of the site and land surrounding the site may change. It is conservatively assumed that land surrounding the landfill could be converted to residential use in the future, and private wells could be installed to provide drinking water for new homes in the area. Future use of the groundwater is unlikely because the base has an existing water supply, but cannot be ruled out. Under an assumption of future residential use of land surrounding the landfill, the following potential exposure pathways are identified:

- Ingestion of contaminated groundwater as drinking water.
- Dermal contact with contaminated groundwater while bathing or showering, or through other household uses.
- Consumption of homegrown fruits and vegetables watered with groundwater.

All these exposure pathways, in addition to those evaluated under conditions of current land use, were evaluated in the RI Risk Assessment. In this Supplemental Risk Assessment, consumption of homegrown fruits and vegetables watered with groundwater is not evaluated. This is because the health risks associated with this pathway represent approximately 0.02 to 3 percent of the total risk from groundwater exposures (see Appendix Y and Subsection 6.1.2.2 for more discussion). In addition, confidence in the risk estimates generated for the other three groundwater exposure pathways is much higher than for the irrigation pathway. The modeling of contaminant uptake and absorption by plants, and subsequent absorption by humans, introduces substantial uncertainty into the exposure assessment without affecting any conclusions regarding total site risk.

With few exceptions, the exposure parameter value assumptions made in the RI Risk Assessment are made in this Supplemental Risk Assessment. For the groundwater exposure pathway, an area resident is assumed to consume COPCs in the groundwater (at 2 liters per day for 350 days per year) for a residential lifetime of 30 years (the national upperbound time [90th percentile] at one residence) at both average and maximum EPCs. This area resident is also assumed to contact COPCs in the groundwater during showering. Because children represent a potentially sensitive subpopulation, the health risks to children from exposure to COPCs in the groundwater were also evaluated. A

child was assumed to be exposed for a five-year period between the ages of one and six. Table 6-41 contains the exposure parameter values for the groundwater exposure pathway.

Appendix M contains all of the spreadsheets (Tables M-1 through M-8) used to estimate health risks for the groundwater exposure pathway. Equations used to calculate COPC intakes are shown on the spreadsheets as well as all exposure parameter values with their references. Exposure parameter values used to estimate risks to adults are standard values prescribed in USEPA Risk Assessment Guidance (USEPA, 1989b; USEPA, 1989f; USEPA, 1991b). For children, appropriate exposure parameter values were taken from USEPA's Exposure Factors Handbook (USEPA, 1989b). Except for the use of a normalized surface area for a child, the exposure parameter values are the same as in the RI Risk Assessment.

In the RI Risk Assessment, health risks from the consumption of fish in Cold Spring Brook Pond were estimated by multiplying measured sediment concentrations by bioaccumulation factors. The lack of actual fish tissue concentrations was identified in the RI Report as a data gap. For this Supplemental Risk Assessment, measured fish tissue COPC concentrations are used to estimate COPC intakes. Tables M-9 through M-12 in Appendix M are the spreadsheets used to estimate COPC intakes from fish consumption. A recreational fisherman or family member is assumed to obtain 5 percent of his recreationally caught fish from Cold Spring Brook Pond for 30 years. He consumes these fish at the USEPA-prescribed ingestion rate for recreational fishing (54 grams/day or about two 8-ounce servings per week; USEPA, 1991b). A child is assumed to ingest fish at a rate of 16.5 grams/day (USEPA, 1989b); this assumption is different from the RI Risk Assessment that assumed the same ingestion rate as an adult. Table 6-42 contains the exposure parameter values for the fish ingestion pathway.

In the RI Risk Assessment, under assumed future residential use of land surrounding Cold Spring Brook Pond, 50 percent of a fisherman's recreational catch was obtained from Cold Spring Brook Pond. For this Supplemental Risk Assessment, only 5 percent is assumed. This is considered to be a more realistic estimate for the following reasons:

- Based on the October 1992 fish sampling program, it appears that most of the fish in the pond are below the legal catch limits (i.e., minimum lengths) established in the Commonwealth of Massachusetts' Fish and Wildlife Laws. To enable enough fish to be caught for tissue analysis, it was necessary to obtain an amended fishing permit that allowed for smaller size fish (below legal catch limits) to be caught (Division of Fisheries and Wildlife Scientific Collecting Permit for Fish, issued to ABB-ES on October 9, 1992 as amended on October 23, 1992).

- USEPA guidance for evaluating the health risks from fish ingestion recommends assessing this exposure pathway "when there is access to a contaminated water body large enough to produce a consistent supply of edible-sized fish over the anticipated exposure period" (USEPA, 1991b). Additional guidance also states that the consumption rate for recreational fishermen be used when there is a large body of water present (USEPA, 1989b). Cold Spring Brook Pond is approximately 3.5 acres in area and is not stocked. Other larger ponds in the Fort Devens area that are stocked provide better fishing with larger fish populations. Cold Spring Brook Pond does not appear to be a large enough water body to sustain a consistent supply of edible fish.

For the sediment exposure pathway, an individual is assumed to contact the average and maximum detected concentrations of COPCs in sediment for a period of 10 years. Under current land use, an adolescent is assumed to visit the pond five days per year. Under assumed future land use conditions, an adolescent is assumed to visit the pond more frequently, at a rate of 100 days per year. Table 6-43 contains the exposure parameter values for the sediment ingestion pathway. Tables M-13 through M-16 in Appendix M are the spreadsheets used to estimate COPC intakes from sediment contact. Exposure parameter values are shown with their reference. Except for the use of a normalized surface area for a child, all values are the same as in the RI Risk Assessment.

EPCs for the three exposure pathways are provided in Tables 6-36 through 6-39. For groundwater, EPCs were calculated for the downgradient wells. EPCs for fish tissue were calculated using the October 1992 sampling results for Cold Spring Brook Pond. For sediment, as discussed in Subsection 6.2.2.1, EPCs were

calculated using the nine sediment samples collected and analyzed for as part of the RI Report and the 16 sediment samples collected as part of this RI Addendum.

The RI Risk Assessment estimated health risks under USEPA standard exposure assumptions as well as MADEP standard assumptions. As discussed in Subsection 6.1.2.2 and as agreed upon with the regulatory agencies during the May 14, 1993 meeting on risk assessment methodologies for the Supplemental Risk Assessment, only USEPA exposure assumptions and risk estimates will be produced here.

6.2.2.3 Toxicity Assessment. Tables 6-44 and 6-47 contain the dose/response values used to estimate excess lifetime cancer risks and noncarcinogenic health risks. USEPA's IRIS, HEAST, and ECAO were used to identify these values. Cancer slope factors were identified for carcinogens and RfDs or RfCs were identified for noncarcinogens (compounds that exhibit threshold effects).

For carcinogens, Tables 6-44 and 6-46 report both the quantitative measure of carcinogenic potency (i.e., the oral slope factor and adjusted dermal slope factor) and the USEPA's weight-of-evidence classification for the compound. USEPA has developed five weight-of-evidence categories; Subsection 6.1.2.3 describes them.

For noncarcinogens, Tables 6-45 and 6-47 report RfDs for COPCs at Cold Spring Brook Landfill. USEPA defines an RfD as the average daily exposure level below which significant adverse noncarcinogenic health effects are not expected to occur, based on a lifetime of exposure.

Because the toxicity of a noncarcinogen may vary depending on the duration of exposure, both chronic and subchronic RfDs are reported. In the Supplemental Risk Assessment, the majority of exposure scenarios involve chronic exposures (greater than seven years in duration, by USEPA definition). The only exposure scenarios involving subchronic exposures are those of a child ingesting groundwater and consuming fish for five years; subchronic dose/response values were used for these scenarios.

The RI Risk Assessment discusses uncertainties and limitations related to the methods of deriving dose/response values for use in human health risk

assessment. These will not be repeated here. Only those limitations or assumptions specific to the Supplemental Risk Assessment will be discussed here.

Arsenic is a COPC detected in groundwater, sediment, and fish tissue at Cold Spring Brook Landfill. Use of the cancer slope factor for arsenic to estimate excess lifetime cancer risks is thought by many to overestimate the true risk.

In addition to arsenic, other uncertainties or limitations exist in the use or lack of dose/response values for some COPCs at Cold Spring Brook Landfill. These are summarized below:

- Six carcinogenic PAHs were detected in Cold Spring Brook Pond sediment. Because five PAHs (benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene) of the six lack cancer slope factors, the slope factor for benzo(a)pyrene was used as a surrogate value. This is expected to overestimate the cancer risks from exposure to these PAHs because the potency of these PAHs relative to benzo(a)pyrene is less, by factors of approximately 10 and 100 (USEPA, 1992; ICF-Clement Associates, 1987; Nisbet, I. and LaGoy, P., 1992). In addition, several PAHs do not have reference doses; these include acenaphthylene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, chrysene, indeno(1,2,3-cd)pyrene, and phenanthrene. The reference dose for naphthalene was assigned to these PAHs as a surrogate. This may result in an overestimate or underestimate of risk.

- Several inorganic analytes could not be evaluated quantitatively because of a lack of dose/response values. These include aluminum, calcium, cobalt, copper, iron, lead, magnesium, potassium, and sodium. Except for lead, this would not be expected to change the results of the risk assessment significantly. These analytes are common nutrients or essential nutrients with relatively low toxicity.

- A reference dose does not exist for dibenzofuran. However, dibenzofuran was detected in only two of 25 samples, at a maximum concentration of 0.61 ug/g.

Table 6-48 contains default absorption fractions used in the estimation of COPC intake. At the direction of USEPA Region I, default absorption fractions are taken from the Region I Supplemental Risk Assessment Guidance Document (USEPA, 1989c). Following USEPA Region I guidance, the agency's guidance document entitled "Dermal Exposure Assessment: Principles and Applications", Interim Report, January 1992 (USEPA, 1992d) has been followed in assessing the health risks associated with dermal contact with COPCs. Appendix V contains a description of how information provided in the dermal guidance document is used in this Supplemental Risk Assessment. Appendix W contains spreadsheets used to estimate permeability constants per event, a composite variable representing several of the variables discussed in Appendix V.

6.1.2.4 Risk Characterization. In this risk characterization, risk estimates are produced by combining COPC intakes estimated in the Exposure Assessment and dose/response values in the Toxicity Assessment. In addition, the method for estimating both excess lifetime cancer risks as well as possible noncarcinogenic adverse effects is described. The effects of uncertainties in the risk estimates are also discussed.

Tables 6-49 and 6-50 are summaries of the cancer and noncancer risk estimates for Cold Spring Brook Landfill under conditions of current land use. Excess lifetime cancer risks associated with the ingestion of fish from Cold Spring Brook Pond and visitor contact with sediment fall within the Superfund target risk range of $1x10^{-6}$ to $1x10^{-4}$ for carcinogens. The associated HIs are all below one. The risks faced by a trespasser contacting sediment in Cold Spring Brook Pond under an assumed frequency of five days per year for 10 years range from $1x10^{-6}$ to $6x10^{-6}$, under current land use, and from $2x10^{-5}$ to $1x10^{-4}$, under future land use. The risks faced by a recreational fisherman or member of his/her family who consumes fish from Cold Spring Brook Pond range from $1x10^{-6}$ to $9x10^{-6}$; the fisherman is assumed to ingest fish at the USEPA-prescribed ingestion rate of 54 grams per day (or two 8-ounce servings per week) and to obtain 5 percent of recreationally caught fish from Cold Spring Brook Pond. As estimated in the RI Report (April 1993), the health risks associated with contact with surface soil at Cold Spring Brook Landfill fall below the USEPA point of departure of $1x10^{-6}$

excess cancer risk and the target hazard index of one. The cancer risks range from $2x10^{-7}$ to $6x10^{-7}$ and the hazard indices range from 0.000009 to 0.0001. Under current land use conditions, an adult and child were assumed to be exposed to soil by dermal contact and incidental ingestion five days per year for 30 and 5 years, respectively.

Total site risks were calculated in Tables 6-49 and 6-50 to estimate the health risks that a receptor might face who could potentially be exposed by more than one exposure pathway. Under current land use conditions, an adult was assumed to ingest fillets from Cold Spring Brook Pond for 30 years, and contact the pond sediment and soil as a site visitor. The excess lifetime cancer risks for this receptor range from $7x10^{-6}$ to $2x10^{-5}$. The total site cancer risks for a child (age 1-6) were assumed to come from the ingestion of fillets and contact with soil as a site visitor, and range from $1x10^{-6}$ to $3x10^{-6}$. Total site noncancer risks for an adult exposed to COPCs in Cold Spring Brook Pond fillets and landfill surface soil range from 0.07 to 0.1. For a child exposed by the same pathways, the total site noncancer risks range from 0.09 to 0.1.

Tables 6-51 and 6-52 are summaries of the cancer and noncancer risk estimates under the assumption of future residential use of land surrounding the landfill. Because the exposure assumptions for fish ingestion are the same under conditions of current and future land use, the risks are the same. Under future land use conditions, the frequency of sediment contact is assumed to be greater than under current conditions (100 days per year for 10 years instead of five days per year for 10 years). Therefore, the health risks under future conditions are predicted to be slightly higher than under current conditions. The risks faced by a visitor contacting sediment in Cold Spring Brook Pond, under future use conditions, range from $2x10^{-5}$ to $1x10^{-4}$. These risks fall within the Superfund target risk range. Arsenic and PAHs in the sediment account for 100 percent of the risk. As estimated in the RI Report (April 1993), the health risks associated with surface soil exposure under future assumed residential conditions (350 days/year) range from excess cancer risks of $1x10^{-5}$ to $4x10^{-5}$ to hazard indices of 0.0006 to 0.007.

The use of groundwater from the downgradient wells for domestic purposes also poses risks above the points of departure. The cancer risks associated with unfiltered groundwater consumption range from $1x10^{-5}$ to $2x10^{-4}$. Arsenic accounts for about 97 percent of the total risk. An organic compound,

bis(2-ethylhexyl)phthalate, also presents risk slightly above the point of departure, at $5x10^{-6}$; however, it accounts for less than 3 percent of the total risk. The HQs for manganese exceed one; they range from 4 to 10.

Under the assumption of future residential use of land surrounding the landfill, the total site risks for a receptor exposed concurrently (for 30 years) to COPCs in groundwater, landfill soil, and Cold Spring Brook Pond sediment and fish range from $1x10^{-4}$ to $3x10^{-4}$. The total site risks for a child (age 1-6) were assumed to come from the ingestion of fillets, soil contact, and groundwater exposure, and range from $3x10^{-5}$ to $7x10^{-5}$. For an adult exposed to COPCs in fillets, surface soil, and unfiltered groundwater, the total site hazard index ranges from 4 to 9. For a child, exposed concurrently by the same pathways, the total hazard index ranges from 4 to 10.

6.2.2.5 Comparison of EPCs to Standards and Guidelines. The FDA issues action levels for contaminants in fish (USFDA, 1992). Action levels are established by the FDA to control levels of contaminants in human food and animal feed. The FDA has issued action levels for three of the COPCs detected in either the pumpkinseeds, bullhead, or pickerel evaluated in this Supplemental Risk Assessment. Table 6-53 contains these action levels. The maximum detected concentrations of mercury, DDE, and DDD in the fish at Cold Spring Brook Pond are below their respective FDA action levels.

Table 6-54 contains drinking water and groundwater standards and guidelines for COPCs detected in groundwater at Cold Spring Brook Landfill. Average and maximum detected concentrations of COPCs are provided as well. The maximum detected concentrations of several analytes exceed a SMCL or guideline. SMCLs, standards developed to protect against unacceptable aesthetic effects, are exceeded for aluminum, iron, and manganese. (Aluminum was not detected in the filtered samples.) Manganese was detected at concentrations above its proposed federal MCL. The federal and state guidelines for sodium in drinking water were also exceeded. Sodium guidelines have been set for people on sodium-restricted diets. The primary MCL for bis(2-ethylhexyl)phthalate (6 μg/L) was exceeded only by its maximum detected concentration; the average concentration of 4 μg/L is below the MCL.

6.4 Summary of Supplemental Risk Assessments

Supplemental Risk Assessments have been performed at Shepley's Hill Landfill and Cold Spring Brook Landfill to update the RI Risk Assessments completed in April 1993. Since the RI was completed, additional data have been collected to fill data gaps identified in the RI. Additional data reported in this RI Addendum include fish tissue and sediment concentrations at Plow Shop Pond and Cold Spring Brook Pond and new groundwater data (March and June 1993 sampling rounds) for Shepley's Hill Landfill and Cold Spring Brook Landfill. The Supplemental Risk Assessment summaries provided below integrate the findings of the RI and RI Addendum Risk Assessments to give a complete picture of the potential health risks associated with the two landfills.

6.4.1 Shepley's Hill Landfill

In the RI Risk Assessment, potential human health risks were identified through exposure to the following media and site-related COPCs:

- Direct contact with arsenic in sediment along the western shoreline of Plow Shop Pond.
- Consumption of fish assumed to contain arsenic and cadmium.
- Residential use of groundwater interpreted to be under the influence of the landfill and contaminated with arsenic, Aroclor-1260, beryllium, cadmium, manganese, and six other COPCs that contributed less than 1 percent to the total risk.

Other contaminants interpreted in the RI to be from sources other than Shepley's Hill Landfill also contributed to the total risks. These included the pesticides heptachlor and DDE in fish, as well as mercury. Non-landfill-related COPCs (beryllium and PAHs) were also reported in sediment along the eastern shoreline of Plow Shop Pond at risks only slightly above USEPA's risk management guidelines. Groundwater from two well groupings in the RI Risk Assessment interpreted to be outside the zone of influence of Shepley's Hill Landfill also presented health risks above USEPA guidelines.

In this Supplemental Risk Assessment, additional data and analysis allowed for the refinement of the risk estimates generated in the RI Risk Assessment. Figures 6-1 through 6-4 present risk estimates produced in the Supplemental Risk Assessment in relation to USEPA risk management guidelines. Actual fish tissue analyses obtained through the October 1992 fish sampling program provided measured COPC levels in fish. The health risks faced by a recreational fisherman or family member who consumes fish from Plow Shop Pond range from $3x10^{-6}$ to $4x10^{-4}$. Arsenic in the fish accounts for approximately 96 to 99 percent of the total risk. Mercury, a COPC not considered to be landfill-related, presents noncancer risks above the regulatory guideline of one (HQs range from 2 to 7). Detected concentrations of mercury in the bullhead and bass fillets in Plow Shop Pond also exceed the FDA action level for mercury of 1 ppm. One additional COPC not related to the landfill, DDE, presents a cancer risk of $2x10^{-6}$, which represents only 0.4 to 4 percent of the total risk.

While the risk estimates associated with arsenic in Plow Shop Pond fish exceed the USEPA points of departure, these risk estimates are thought to overestimate the true risks. Arsenic in fish exists largely as organic forms that possess minimal inherent toxicity and are believed to possess no mutagenic or carcinogenic potential. All of the arsenic in Plow Shop Pond fish has been assumed to be inorganic; the analytical methods for inorganics used in the RI Addendum do not distinguish between the organic and inorganic forms of a metal. Furthermore, the cancer slope factor for inorganic arsenic is thought by many to overestimate the true risk. The USEPA IRIS file (December 1993) on inorganic arsenic states that "the uncertainties associated with ingested arsenic are such that estimates could be modified downwards as much as an order of magnitude, relative to risk estimates associated with most other carcinogens." If a modifying factor of 10 were applied to the unmodified risk estimates for the fish ingestion pathway, modified cancer risk estimates would range from $3x10^{-7}$ to $4x10^{-5}$ -- risks within or below the Superfund target risk range of $1x10^{-6}$ to $1x10^{-4}$. Because the true risks associated with arsenic in Plow Shop Pond are thought to be significantly lower than initially calculated, it appears that the major health risk associated with Plow Shop Pond fish is due to mercury contamination.

In the Supplemental Risk Assessment, direct contact with sediment presented cancer risks (unmodified to account for the uncertainty associated with arsenic) ranging from $2x10^{-5}$ to $2x10^{-4}$ (under current land use) and $9x10^{-5}$ to $6x10^{-4}$ (under future land use). Arsenic is responsible for essentially 100 percent of the

risk. As in the RI Risk Assessment, these risks are above the USEPA point of departure of $1x10^{-6}$ but, under average exposure conditions, within the Superfund target risk range of $1x10^{-6}$ to $1x10^{-4}$. Only under maximum exposure conditions does the cancer risk exceed the upper end of the target risk range (at $2x10^{-4}$ and $6x10^{-4}$). If the modifying factor of 10 were applied to the cancer risk estimates for arsenic, cancer risk estimates would range from $2x10^{-6}$ to $2x10^{-5}$ (under current land use) and $9x10^{-6}$ to $6x10^{-5}$ (under future land use); these risks are within the Superfund target risk range.

Cadmium was reported in the RI Risk Assessment to present a health risk of potential concern in Plow Shop Pond fish. This was not confirmed in the Supplemental Risk Assessment. In the RI Risk Assessment, actual fish tissue concentrations were not yet available; the risks were estimated by multiplying measured sediment concentrations by bioaccumulation factors. While cadmium was detected in sediment in the RI, and attributed to the landfill, this is not true in the RI Addendum. Cadmium was detected infrequently in RI Addendum sediment samples and was not interpreted to be a landfill-related COPC. Furthermore, cadmium was not detected in the bluegills or fillets (bullhead and bass) in Plow Shop Pond that were evaluated in the Supplemental Risk Assessment.

The health risks from lead in Plow Shop Pond fish or sediment could not be estimated quantitatively either in the RI or Supplemental Risk Assessments because of the lack of a USEPA-approved dose/response value for lead. Lead was detected in one of five bluegills in Plow Shop Pond, but not in the bullhead or bass fillets. The concentrations of lead in sediment can be evaluated using the USEPA interim soil cleanup level for lead for residential settings of 500 $\mu g/g$ (USEPA, 1989g). Although the maximum detected concentration of lead in Plow Shop Pond (632 $\mu g/g$) sediment is above this soil lead cleanup level, the average concentration of lead in Plow Shop Pond is 125 $\mu g/g$. Exposure to lead in sediment at Plow Shop Pond is also expected to much less than in a residential setting. Therefore, lead is not expected to pose a significant health risk in Plow Shop Pond sediment.

Groundwater sampling data from the March and June 1993 sampling rounds (reported in this RI Addendum) confirm the RI Risk Assessment conclusion that the health risks associated with residential use of the groundwater exceed the USEPA points of departure and Superfund target risk range. The cancer risks

(unmodified to account for the uncertainty associated with arsenic) from groundwater consumption (from Well Group 1) range from $8x10^{-5}$ to $2x10^{-3}$. As in the RI Risk Assessment, most of the risk is due to the presence of arsenic. The hazard quotients for manganese exceed one; they range from 2 to 16. the two organic analytes, 1,2-dichloroethane and dichlorobenzenes, presented cancer risks of $6x10^{-6}$ and $3x10^{-6}$, respectively -- within the Superfund target risk range. If the downward modifying factor of 10 were applied to the unmodified cancer risk estimates for arsenic, the modified risks would range from $8x10^{-6}$ to $2x10^{-4}$. It should be noted that even when the concentration of arsenic in groundwater is assumed to be at the federal MCL of 50 μg/L, the cancer risk associated with the MCL ($1x10^{-3}$) exceeds the Superfund target risk range and its HQ (of 5) exceeds one.

The suite of other chemicals contributing to the total risk varies, however, between the RI and Supplemental Risk Assessments. In the RI Risk Assessment, other chemicals in the groundwater contributing to the total risk (at risks above the points of departure) included Aroclor-1260, beryllium, cadmium, manganese, heptachlor, and some VOCs (benzene, chloroform, 1,2-dichloroethane, methylene chloride, and 1,1,2,2-tetrachloroethane). In the Supplemental Risk Assessment, using the latest groundwater samples (from two rounds) and a landfill well grouping slightly different from the RI well group, three compounds besides arsenic contribute to the total risk at risk levels above the points of departure - 1,2-dichloroethane, dichlorobenzenes, and manganese. Aroclor-1260 and 1,1,2,2-tetrachloroethane were detected during RI sampling in wells no longer interpreted to be under the influence of Shepley's Hill Landfill. In addition, they were not detected in Supplemental RI sampling. Although benzene was detected in the RI Addendum sampling (in 3 of 14 samples), it no longer presented a cancer risk above the USEPA point of departure. Chloroform is not a COPC in the Supplemental Risk Assessment. Four other RI COPCs, heptachlor, methylene chloride, beryllium, and cadmium, were not detected in the RI Addendum sampling rounds. Chloroform was detected, but considered an artifact of decontamination procedures.

In comparing the March and June 1993 sampling results to drinking water standards, for Well Group 1, the maximum detected concentrations of several analytes in unfiltered groundwater exceed a primary (or health-based) federal or state drinking water standard (see Table 6-31). These include: 1,2-dichloro-ethane, dichlorobenzenes, arsenic, chromium, lead, and nickel. Based on filtered

samples, however, the maximum concentration of lead is below the federal action level for lead. Neither chromium nor nickel were detected in filtered samples. Manganese was detected at concentrations above its proposed federal MCL. Dichlorobenzenes (isomers unidentified) were detected in one of 14 samples; while the maximum exceeds the state drinking water guideline for p-dichlorobenzene (the isomer with the lowest guideline), the average (5.4 μg/L) approximates the guideline (5 μg/L). While the maximum detected concentration of 1,2-dichloroethane (9.9 μg/L) exceeds the federal MCL of 5 ug/L, the average concentration of 0.97 μg/L does not exceed the MCL. Secondary Maximum Contaminant Levels (SMCLs), standards developed to protect against unacceptable aesthetic effects (such as appliance or clothes staining or taste) are exceeded for aluminum, iron, and manganese. The federal and state guidelines for sodium in drinking water were also exceeded. Sodium guidelines have been set for people on sodium-restricted diets.

6.4.2 Cold Spring Brook Landfill

In the RI Risk Assessment, potential human health risks were identified through exposure to the following media and site-related COPCs:

- Direct contact with arsenic and PAHs in sediment along the shoreline of Cold Spring Brook Pond.
- Consumption of fish assumed to contain arsenic, zinc, DDD, and DDE.
- Residential use of groundwater interpreted to be under the influence of the landfill and contaminated mainly with arsenic, and to a much lesser degree with beryllium and manganese.

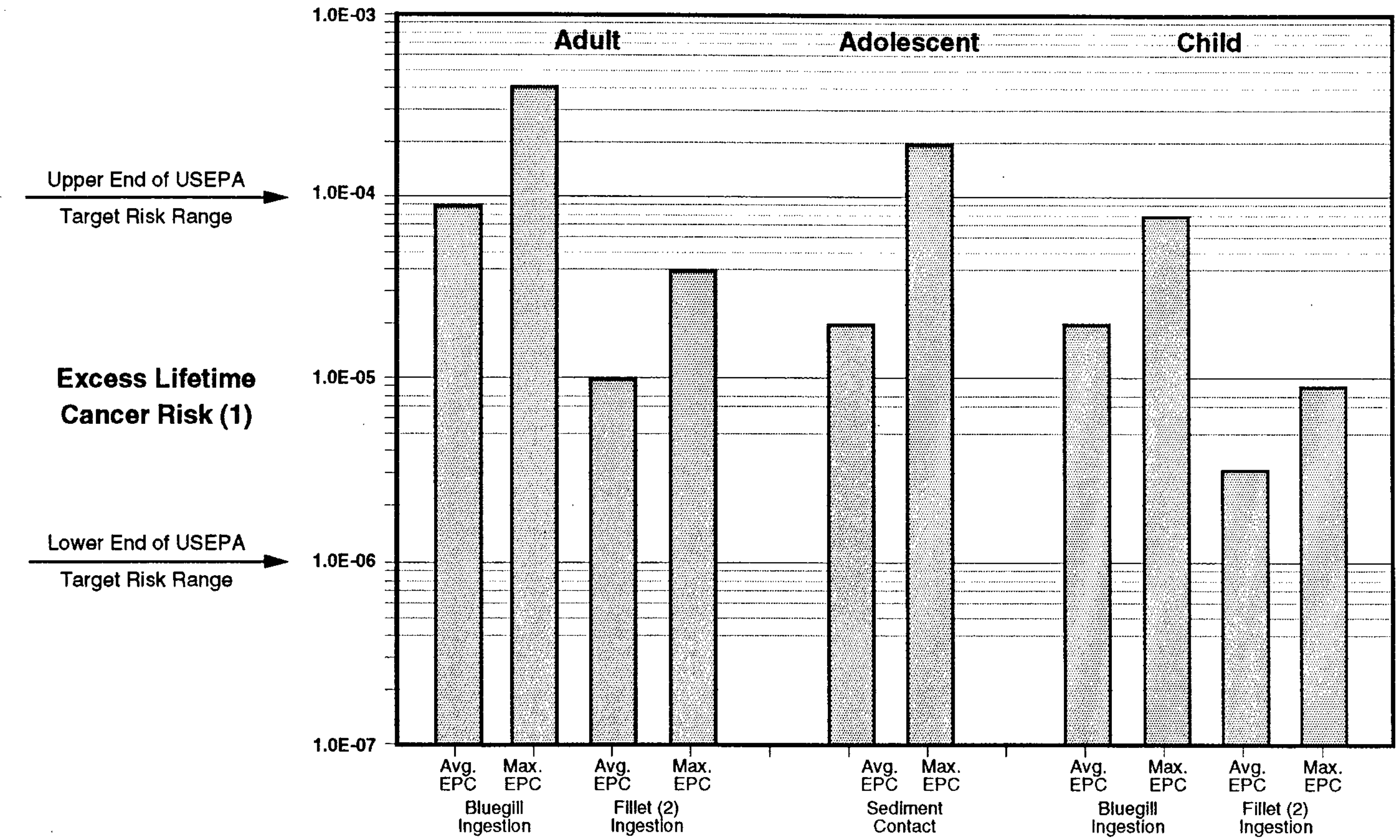
In this Supplemental Risk Assessment, additional data and analysis allowed for the refinement of the risk estimates generated in the RI Risk Assessment. Figures 6-5 through 6-8 present risk estimates produced in the Supplemental Risk Assessment in relation to USEPA risk management guidelines. Actual fish tissue analyses obtained through the October 1992 fish sampling program provided measured COPC levels in fish. The health risks faced by a recreational fisherman or family member of his family who consumes fish from Cold Spring Brook Pond range from $1x10^{-6}$ to $9x10^{-6}$. These risks fall within the Superfund target risk

range. The maximum detected concentrations of mercury, DDE, and DDD in the fish at Cold Spring Brook Pond are also below their respective FDA action levels. These are the only three COPCs for which the FDA has developed action levels.

As estimated in the RI Report (April 1993), the health risks associated with contact with surface soil at Cold Spring Brook Landfill fall below the USEPA point of departure of $1x10^{-6}$ excess cancer risk and target hazard index of one. The cancer risks range from $2x10^{-7}$ to $6x10^{-7}$ and the hazard indices range from 0.000009 to 0.0001. Under current land use conditions, an adult and child were assumed to be exposed to soil by dermal contact and incidental ingestion five days per year for 30 and 5 years, respectively. The health risks associated with surface soil exposure under future assumed residential conditions (350 days/year) range from excess cancer risks of $1x10^{-5}$ to $4x10^{-5}$ to hazard indices of 0.0006 to 0.007. Zinc was reported in the RI Risk Assessment to present a health risk of potential concern in Cold Spring Brook Pond fish. This was not confirmed in the Supplemental Risk Assessment. In the RI Risk Assessment, actual fish tissue concentrations were not yet available; the risks were estimated by multiplying measured sediment concentrations by bioaccumulation factors. In the Supplemental Risk Assessment, the noncancer risks associated with zinc were at least two orders of magnitude below the target HQ of one.

In the Supplemental Risk Assessment, direct contact with sediment presented cancer risks ranging from $1x10^{-6}$ to $6x10^{-6}$, under current land use, and from $2x10^{-5}$ to $1x10^{-4}$, under assumed future land use conditions. As in the RI Risk Assessment, these risks fall within the Superfund target risk range of $1x10^{-6}$ to $1x10^{-4}$.

The health risks from lead in Cold Spring Brook Pond sediment could not be estimated quantitatively either in the RI or Supplemental Risk Assessments because of a lack of a USEPA-approved dose/response value for lead. (Lead was not detected in the Cold Spring Brook Pond fish evaluated in this Risk Assessment.) The concentrations of lead in sediment can be evaluated using the USEPA interim soil cleanup level for lead in residential settings of 500 μg/g (USEPA, 1989g). Although the maximum detected concentration of lead in Cold Spring Brook Pond sediment (570 μg/g) is above the soil lead cleanup level, the average concentration (69.5 μg/g)is below. Exposure to lead in sediment is also expected to be much less than in a residential setting. Therefore, lead in sediment is not expected to pose a significant health risk.



NOTE:

(1) Landfill-related COPCs account for between 96 and 100% of the total risk.

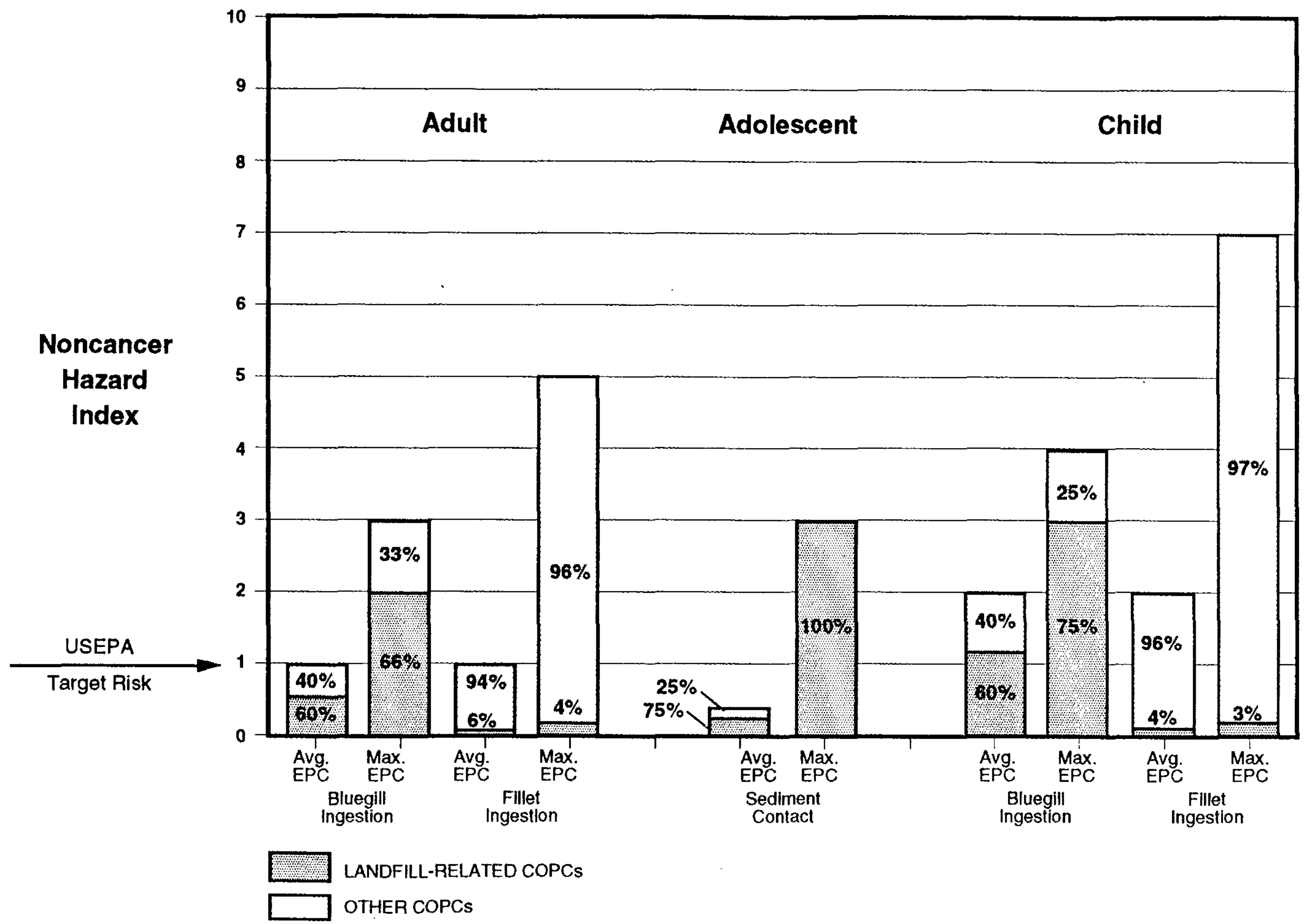
(2) Fillets include bullheads and large mouth bass.

(3) Avg. EPC = average exposure point concentration;
Max. EPC = maximum exposure point concentration.

FIGURE 6-1
SUMMARY OF CANCER RISK ESTIMATES
CURRENT LAND USE SHEPLEY'S HILL LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9312018D (A)



NOTE:

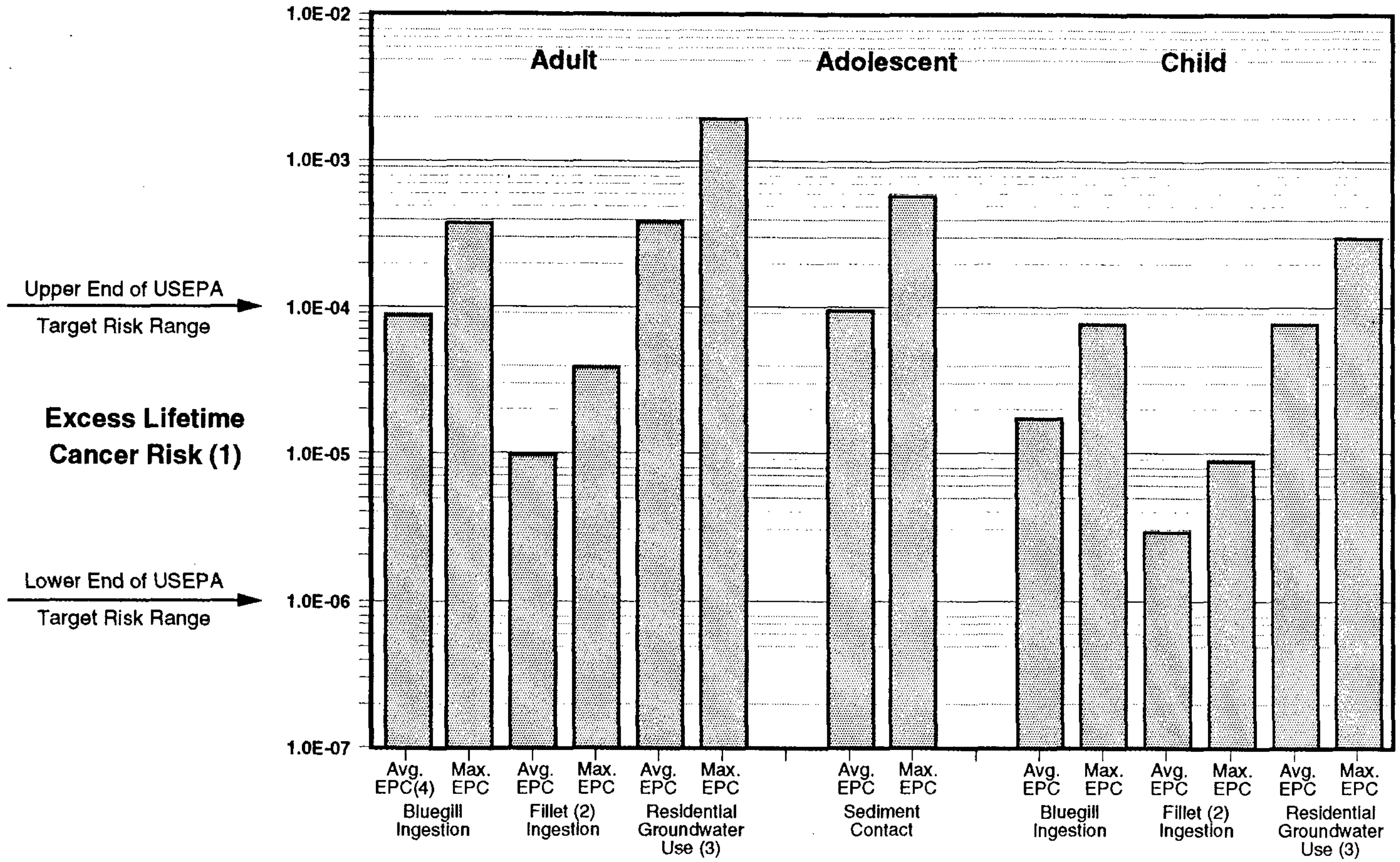
(1) Fillets include bullheads and largemouth bass.

(2) Avg. EPC = average exposure point concentration;
Max. EPC = maximum exposure point concentration.

FIGURE 6-2
SUMMARY OF NONCANCER RISK ESTIMATES
CURRENT LAND USE SHEPLEY'S HILL LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9312018D (G)



NOTE:

(1) Landfill-related COPCs account for between 96 and 100% of the total risk.

(2) Fillets include bullheads and large mouth bass.

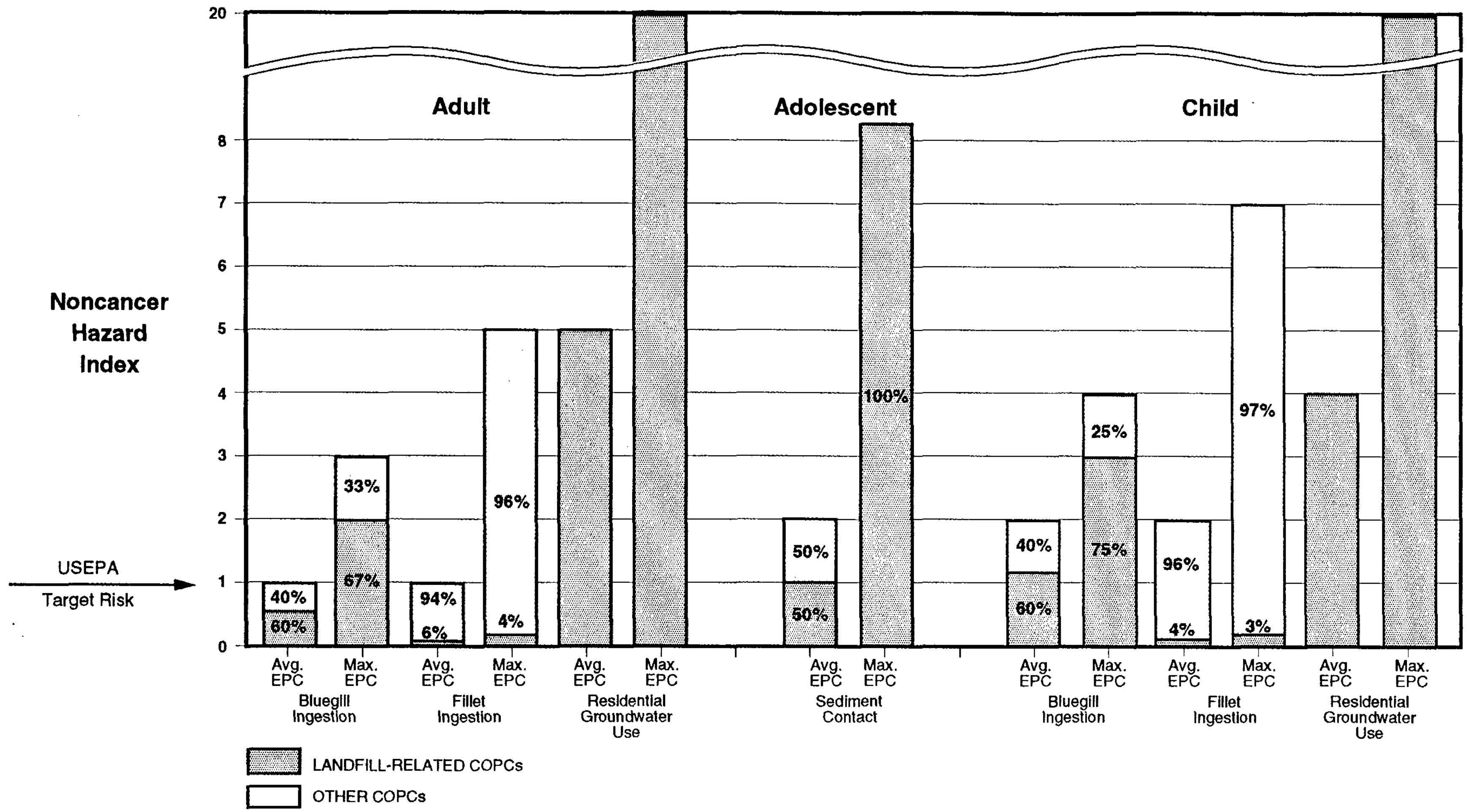
(3) Unfiltered groundwater.

(4) Avg. EPC = average exposure point concentration;
Max. EPC = maximum exposure point concentration.

FIGURE 6-3
SUMMARY OF CANCER RISK ESTIMATES
FUTURE LAND USE SHEPLEY'S HILL LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9312018D (B)

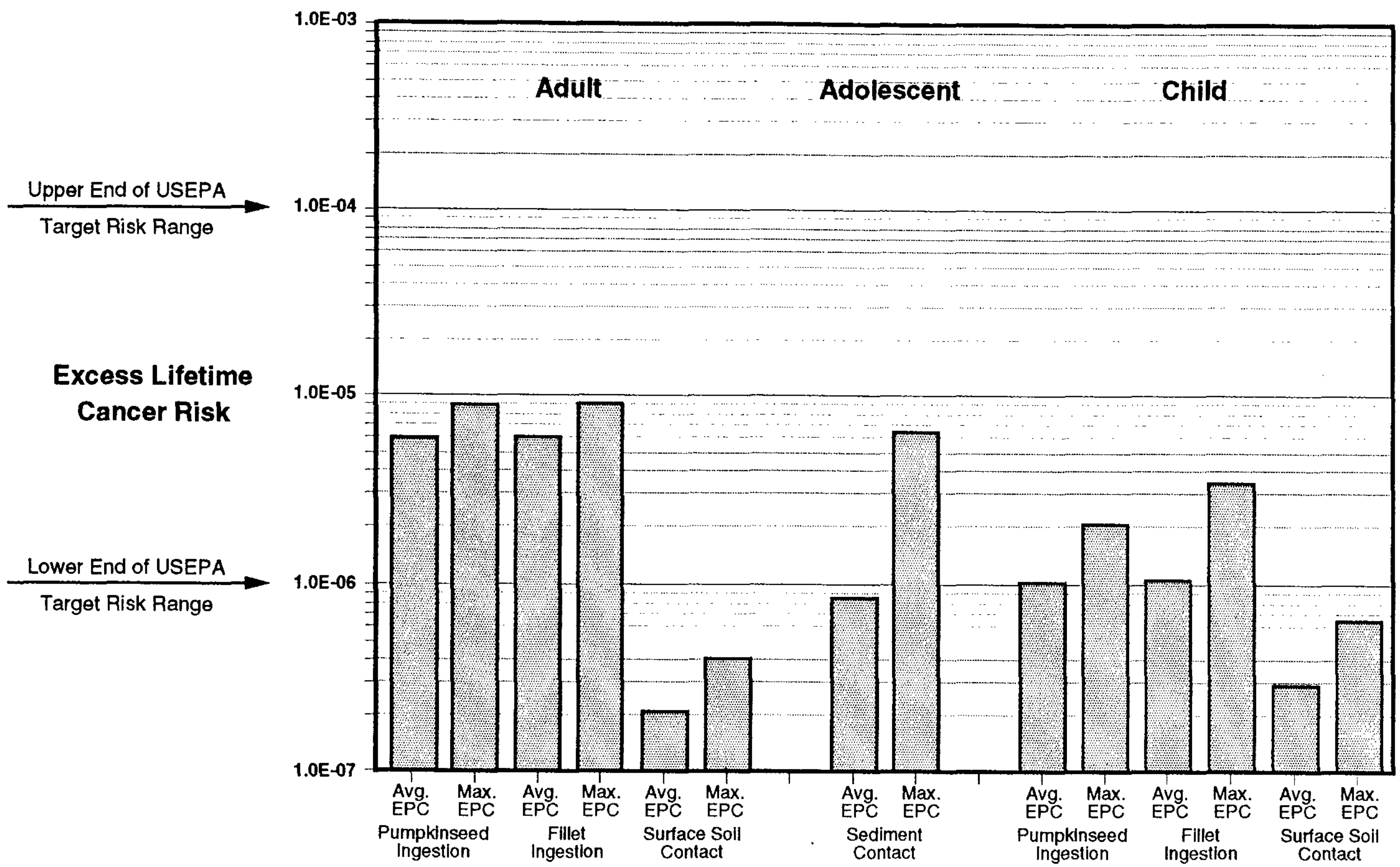


NOTE:
Fillets include bullheads and largemouth bass.
Groundwater estimates are based on unfiltered samples.
AVG.EPC = average exposure point concentration
MAX. EPC = maximum exposure point concentration

FIGURE 6-4
SUMMARY OF NONCANCER RISK ESTIMATES
FUTURE LAND USE SHEPLEY'S HILL LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9312018D (H)



NOTE:

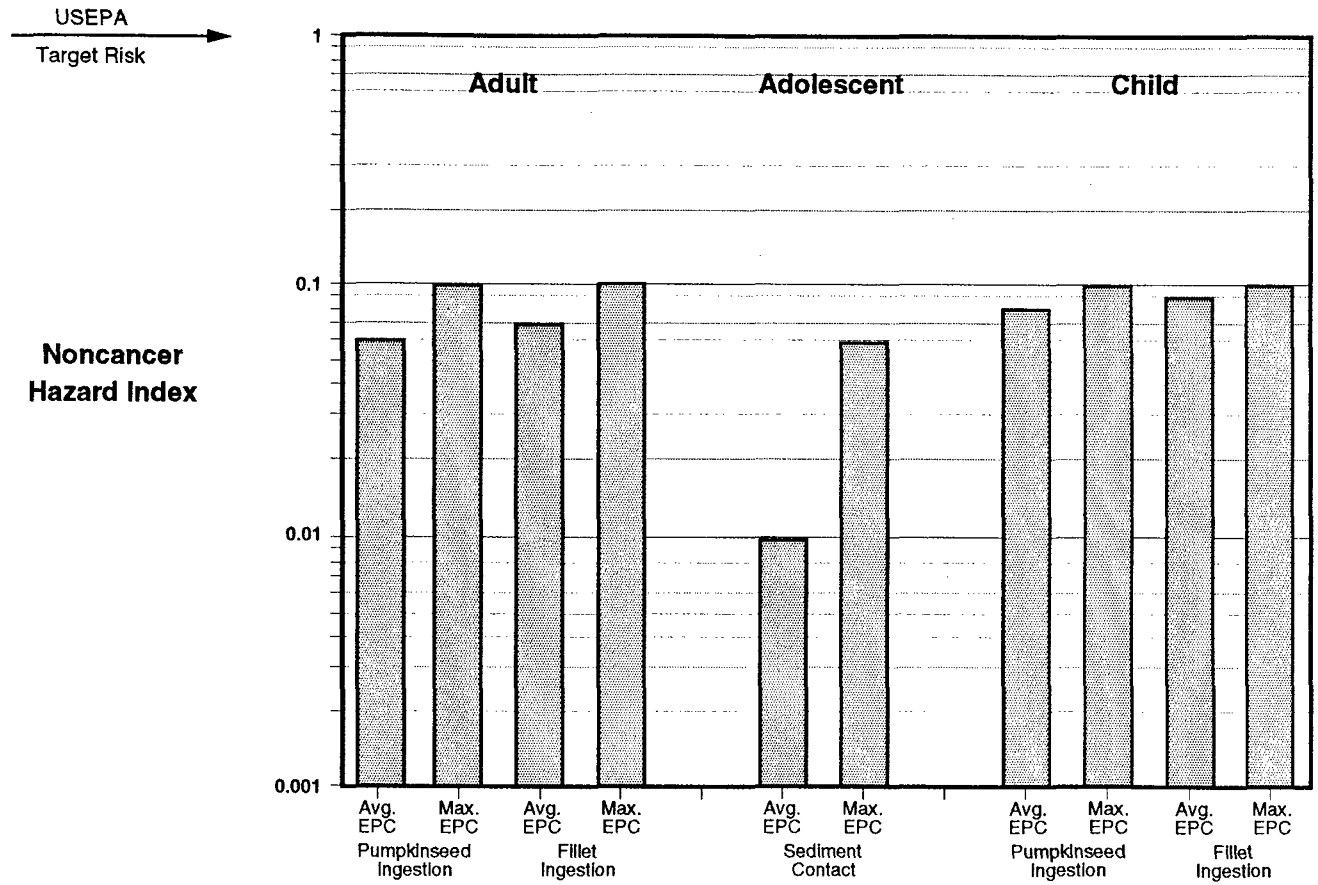
(1) Fillets include bullheads and chain pickerel.

(2) Avg. EPC = average exposure point concentration;
Max. EPC = maximum exposure point concentration.

FIGURE 6-5
SUMMARY OF CANCER RISK ESTIMATES
CURRENT LAND USE COLD SPRING BROOK LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9312018D (D)



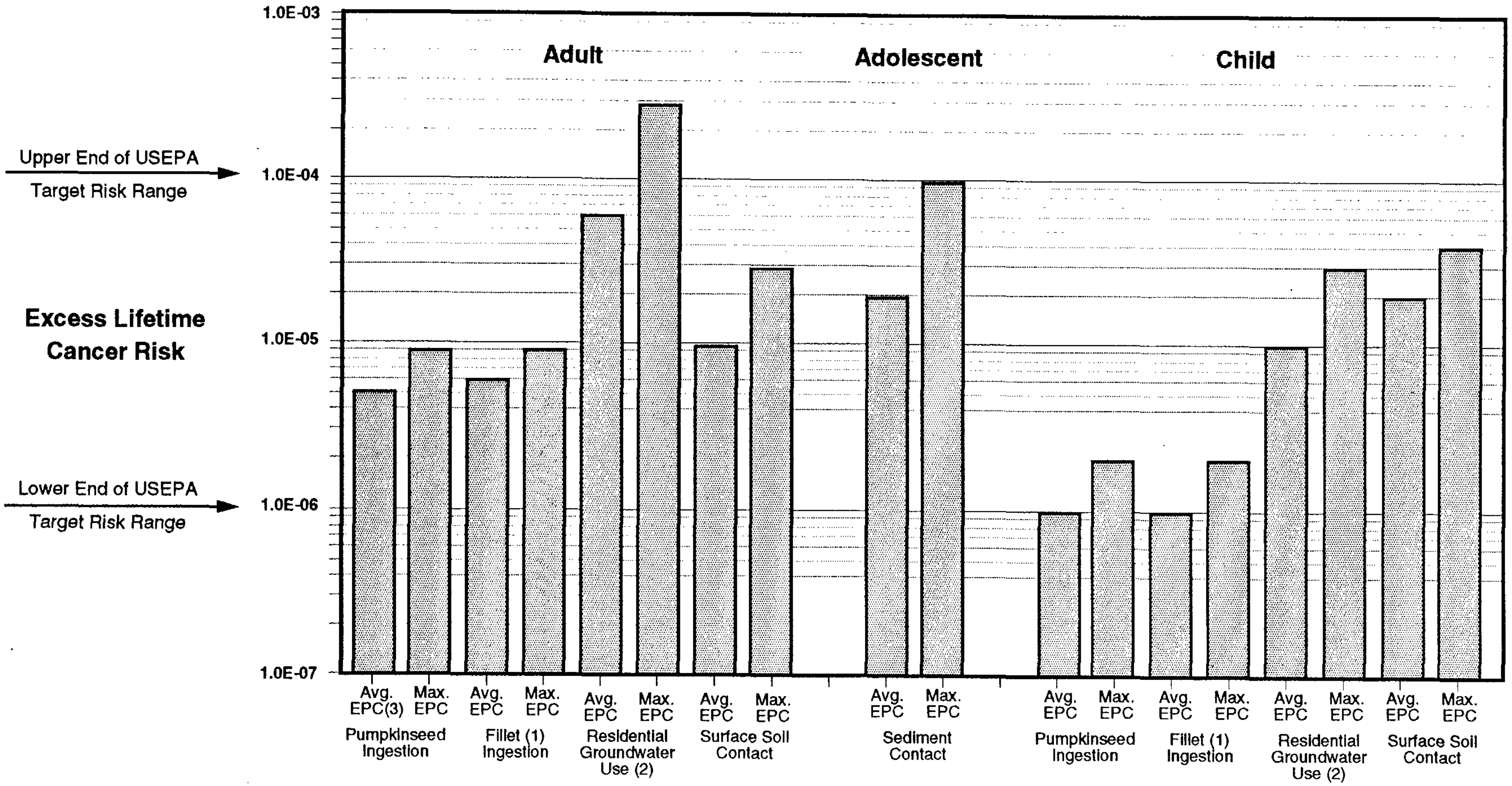
NOTE:

(1) Fillets include bullheads and chain pickerel.

(2) Hazard indices associated with surface soil contact for adult and child are $1x10^{-4}$ or less.

(3) Avg. EPC = average exposure point concentration;
Max. EPC = maximum exposure point concentration.

FIGURE 6-6
SUMMARY OF NONCANCER RISK ESTIMATES
CURRENT LAND USE COLD SPRING BROOK LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA



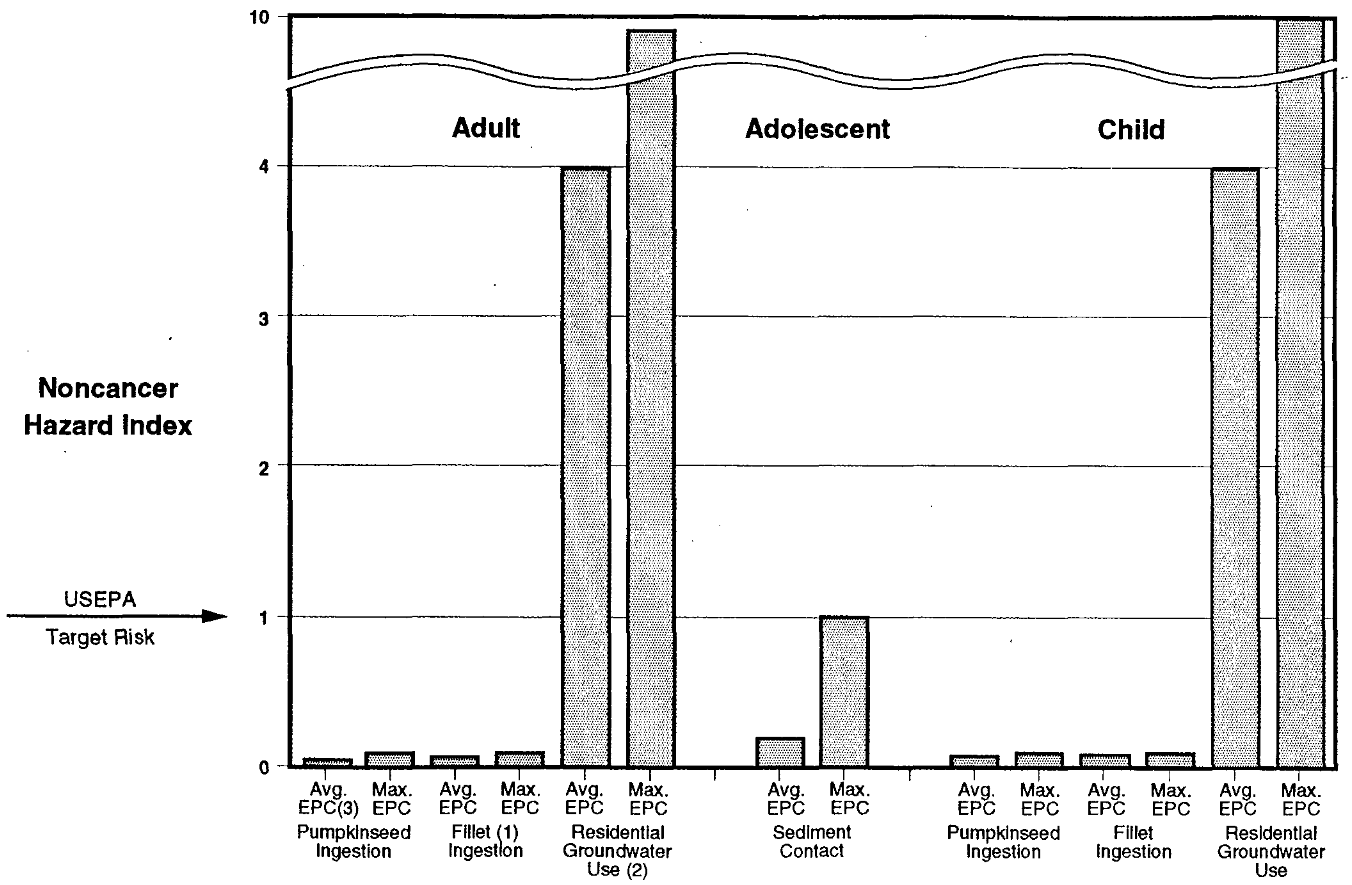
NOTE:

(1) Fillets include bullheads and chain pickerel.

(2) Unfiltered groundwater.

(3) Avg. EPC = average exposure point concentration;
Max. EPC = maximum exposure point concentration.

FIGURE 6-7
SUMMARY OF CANCER RISK ESTIMATES
FUTURE LAND USE COLD SPRING BROOK LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA



NOTE:

(1) Fillets include bullheads and chain pickerel.

(2) Unfiltered groundwater.

(3) Avg. EPC = average exposure point concentration;
Max. EPC = maximum exposure point concentration.

(4) Hazard indices for surface soil contact for adult and child are 0.007 or less.

FIGURE 6-8
SUMMARY OF NONCANCER RISK ESTIMATES
FUTURE LAND USE COLD SPRING BROOK LANDFILL
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ABB Environmental Services, Inc.

9312018D (F)

TABLE 6-1

SUMMARY OF RI HUMAN HEALTH RISK ASSESSMENT: SITE-RELATED CONTAMINATION

SHEPLEY'S HILL LANDFILL[1]

REMEDIAL INVESTIGATION ADDENDUM REPORT

FEASIBILITY STUDY FOR GROUP 1A SITES

FORT DEVENS, MA

POTENTIAL EXPOSURE PATHWAY		ESTIMATED EXCESS CANCER RISK			HAZARD INDICES			PRIMARY CONTRIBUTORS TO RISK[2]
		ADULT	ADOLESCENT	CHILD	ADULT	ADOLESCENT	CHILD	
Current Land Use								
Fish Ingestion	Average:	5.5E - 4	--	4.0E - 4	3.1	--	14	Arsenic (>99%), Cadmium (6)
	RME:	1.8E - 3	--	1.3E - 3	9.2	--	40	
Sediment Contact	Average:	--	6.0E - 5	--	--	(0.81)	--	
	RME:	--	1.4E - 4	--	--	1.8	--	Arsenic (100%)
Assumed Future Residential Site Use								
Residential Groundwater Usage	Average:	2.8E - 3	--	5.1E - 4	12	--	13	Arsenic (94%), Aroclor 1260 (3%)
	RME:	1.6E - 2	--	2.9E - 3	77	--	85	Beryllium (1%), Cadmium (9) Manganese (2), other chemicals[3]
Fish Ingestion	Average:	5.5E - 4	--	4.0E - 4	3.1	--	14	
	RME:	1.8E - 3	--	1.3E - 3	9.2	--	40	Arsenic (>99%), Cadmium (6)
Sediment Contact	Average:	--	2.3E - 4	--	--	3.1	--	
	RME:	--	5.2E - 4	--	--	7.1	--	Arsenic (100%)
Total Risk	Average:	3.4E - 3	2.3E - 4	9.1E - 4	15	3.1	27	
	RME:	1.8E - 2	5.2E - 4	4.2E - 3	86	7.1	125	

Notes:

[1] Excerpted from Tables 8-25 through 8-28 of the RI Risk Assessment, April 1993.

[2] In parentheses is the percentage that a carcinogen contributes to the total cancer risk or, for a noncarcinogen, the hazard index.

[3] Other chemicals responsible for risks greater than 10^{-6} but less than 1% of the total risk are benzene, chloroform, 1,2-dichloroethane, heptachlor, methylene chloride, and 1,1,2,2-tetrachloroethane.

TABLE 6-2

SUMMARY OF RI HUMAN HEALTH RISK ASSESSMENT: CONTAMINATION FROM SOURCES OTHER THAN SHEPLEY'S HILL LANDFILL[1]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

POTENTIAL EXPOSURE PATHWAY		ESTIMATED EXCESS CANCER RISK			HAZARD INDICES			PRIMARY CONTRIBUTORS TO RISK[2]
		ADULT	ADOLESCENT	CHILD	ADULT	ADOLESCENT	CHILD	
Current Land Use								
Fish Ingestion	Average:	1.2E − 5	--	8.4E − 6	4	--	17	Heptachlor (66%), DDE (34%)
	RME:	3.9E − 5	--	2.8E − 5	18	--	78	Mercury (77), Copper (1.1)
Assumed Future Residential Site Use								
Fish Ingestion	Average:	1.2E − 5	--	8.4E − 5	4	--	17	Heptachlor (66%), DDE (34%)
	RME:	3.9E − 5	--	2.8E − 5	18	--	78	Mercury (77), Copper (1.1)
Sediment Contact	Average:	--	1.4E − 6	--	--	0.18	--	Beryllium (35%), PAHs (65%)
(East side of shoreline)	RME:	--	2.7E − 6	--	--	0.31	--	
Groundwater Ingestion	Average:	7.5E − 3	--	1.4E − 3	35	--	39	Arsenic (98%), Beryllium (1%)
(SHL−15)	RME:	1.2E − 2	--	2.3E − 3	58	--	65	Dieldrin (<1%), Manganese (2.9) Cadmium (2.7)
Groundwater Ingestion	Average:	4.7E − 4	--	8.7E − 5	2.6	--	2.9	Arsenic (98%), Beryllium (2%)
(SHL−7, −8, −8D, and 13)	RME:	1.5E − 3	--	2.8E − 4	7.7	--	8.4	Manganese (0.8)

Notes:

[1] Excerpted from Tables 8−29 through 8−32 of the RI Risk Assessment, April 1993.

[2] In parentheses is the percentage that a carcinogen contributes to the total cancer risk or, for a noncarcinogen, the hazard index.

TABLE 6-3

COMPARISON OF AVERAGE AND MAXIMUM SURFACE WATER CONCENTRATIONS TO DRINKING WATER STANDARDS PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT FEASIBILITY STUDY FOR GROUP 1A SITES FORT DEVENS, MA

ANALYTES	AVERAGE CONCENTRATION (ug/L)	MAXIMUM CONCENTRATION (ug/L)	DRINKING WATER STANDARDS (ug/L)	
Organics:				
Chloroform	0.740	1.41	100	(1)
Inorganics:				
Arsenic	4.32	6.96	50	(1)
Barium	7.06	15.2	2000	(1)
Chromium	2.41	4.9	100	(1)
Copper	14.2	48.7	1300	(2)
Iron	473	1100	NA	(3)
Manganese	96.5	500	200	(2)
Nickel	15.7	44.2	100	(1)
Silver	0.415	3.6	200	(4)
Zinc	18.4	58.1	11,000	(4)

Notes:

(1) Federal Maximum Contaminant Level (MCL)

(2) Federal Maximum Contaminant Level Goal (MCLG)

(3) NA = No health-based standard is available

(4) USEPA Health Advisory based on lifetime exposure

TABLE 6-4
GROUNDWATER WELL GROUPINGS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

WELL GROUP 1	WELL GROUP 2 (BACKGROUND)	WELL GROUP 3	WELL GROUP 4
SHL-3	SHL-6	SHL-8D	SHL-15
SHL-4	SHL-7**	SHL-8S	
SHL-5	SHL-12*	SHL-13	
SHL-9	SHL-17*	SHL-21*	
SHL-10	SHL-23		
SHL-11	SHL-24		
SHL-18	SHL-25		
SHL-19	SHM-93-24A		
SHL-20			
SHL-22			
SHM-93-01A			
SHM-93-18B			
SHM-93-10C			
SHM-93-22C			

* Placed in Well Group 1 in the RI Risk Assessment
** Placed in Well Group 3 in the RI Risk Assessment

Note:
The following wells were sampled in both Round 1 (March 93) and Round 2 (June 93): SHM-93-01A (unfiltered and filtered), SHM-93-10C (unfiltered), SHM-93-18B (unfiltered and filtered), SHM-93-22C (unfiltered), and SHM-93-24A (unfiltered and filtered).

TABLE 6-5
SUMMARY OF GROUNDWATER SAMPLING RESULTS[1]
SHEPLEY'S HILL LANDFILL - WELL GROUP 1

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION (ug/L)	ARITHMETIC MEAN (ug/L)	COPC (Y/N)
UNFILTERED SAMPLES[2]				
1,1-Dichloroethane	4 / 14	4.4	0.86	Y
1,2-Dichloroethane	5 / 14	9.9	0.97	Y
1,2-Dichloroethene (cis & trans)	6 / 14	7	1.4	Y
1,2-Dichloropropane	1 / 14	0.52	0.27	Y
Acetone	1 / 14	15	7	N
Benzene	3 / 14	1.7	0.51	Y
Chloroethane	1 / 14	5.5	1.3	Y
Chloroform	3 / 14	0.87	0.33	N
Dichlorobenzenes	1 / 14	11	5.4	Y
Toluene	1 / 14	0.56	0.26	N
Aluminum	13 / 14	75500	4259	Y
Antimony	2 / 14	3.3	1.7	Y
Arsenic	12 / 14	390	101	Y
Barium	13 / 14	350	47.6	Y
Calcium	14 / 14	219000	54280	Y
Chromium	5 / 14	115	9	Y
Cobalt	1 / 14	54.6	14	Y
Copper	4 / 14	92.2	8.6	Y
Iron	14 / 14	97400	17608	Y
Lead	10 / 14	66.8	5.2	Y
Magnesium	14 / 14	24000	7603	Y
Manganese	14 / 14	9650	2045	Y
Nickel	1 / 14	177	22.9	Y
Potassium	13 / 14	31800	7119	Y
Sodium	14 / 14	67300	20749	Y
Vanadium	3 / 14	79.1	9.4	Y
Zinc	3 / 14	220	29.4	Y
FILTERED SAMPLES[3]				
Aluminum	1 / 10	236 BB	NA	N
Antimony	1 / 10	3.12	2	Y
Arsenic	6 / 10	270	71	Y
Barium	10 / 10	117	30	Y
Calcium	10 / 10	175000	37402	Y
Iron	7 / 10	91600	14427	Y
Lead	2 / 10	1.52 BB	NA	N
Magnesium	9 / 10	19900	4679	Y
Manganese	10 / 10	9540	1812	Y
Potassium	9 / 10	10600	4127	Y
Sodium	10 / 10	64600	16934	Y
Zinc	1 / 10	25.5	11	Y

Notes:
NA = Not applicable
ug/L = Micrograms per liter
BB = Less than background concentration
[1] From March and June 1993 sampling rounds
[2] Unfiltered samples from monitoring wells SHL-3, SHL-4, SHL-5, SHL-9, SHL-10, SHL-11, SHL-18, SHL-19, SHL-20, SHL-22, SHM-93-01A, SHM-93-10C, SHM-93-18B, SHM-93-22C
[3] Filtered samples from monitoring wells SHL-3, SHL-4, SHL-5, SHL-9, SHL-10, SHL-11, SHL-19 SHL-20, SHM-93-01A, SHM-93-18B

TABLE 6-6
SUMMARY OF GROUNDWATER SAMPLING RESULTS[1]
SHEPLEY'S HILL LANDFILL - WELL GROUP 3

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION (ug/L)	ARITHMETIC MEAN (ug/L)	COPC (Y/N)
UNFILTERED SAMPLES[2]				
Aluminum	2/4	4030 BB	1800	N
Arsenic	2/4	17	8.4	Y
Barium	4/4	28 BB	14	N
Calcium	4/4	15400	1100	Y
Chromium	2/4	7.38 BB	5.1	N
Iron	4/4	5350 BB	2500	N
Lead	2/4	7.38	3.4	Y
Magnesium	4/4	2850 BB	1900	N
Manganese	4/4	1590	680	Y
Potassium	4/4	2080 BB	1900	N
Sodium	4/4	17300	7600	Y
FILTERED SAMPLES[3]				
Barium	1/1	8.71 BB	NA	N
Calcium	1/1	11000 BB	NA	N
Magnesium	1/1	1840 BB	NA	N
Manganese	1/1	114 BB	NA	N
Potassium	1/1	829 BB	NA	N
Sodium	1/1	16400	NA	Y

Notes:
ug/L = Micrograms per liter
NA = Not applicable
BB = Less than background concentration
[1] From March 1993 sampling round.
[2] Unfiltered samples from monitoring wells SHL-8D, SHL-8S, SHL-13, SHL-21.
[3] Filtered samples from monitoring well SHL-13.

TABLE 6-7
SUMMARY OF GROUNDWATER SAMPLING RESULTS[1]
SHEPLEY'S HILL LANDFILL - WELL GROUP 4

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION (ug/L)	ARITHMETIC MEAN (ug/L)	COPC (Y/N)
UNFILTERED SAMPLES [2]				
Trichlorofluoromethane	1 / 1	2.1	NA	Y
Aluminum	1 / 1	1330 BB	NA	N
Arsenic	1 / 1	24	NA	Y
Barium	1 / 1	39.4 BB	NA	N
Calcium	1 / 1	15600	NA	Y
Iron	1 / 1	1840 BB	NA	N
Lead	1 / 1	3.69 BB	NA	N
Magnesium	1 / 1	1900 BB	NA	N
Manganese	1 / 1	1430	NA	Y
Potassium	1 / 1	3260	NA	Y
Sodium	1 / 1	7370 BB	NA	N
Zinc	1 / 1	35.8	NA	Y
FILTERED SAMPLES [3]				
Barium	1 / 1	26.2 BB	NA	N
Calcium	1 / 1	16900	NA	Y
Chromium	1 / 1	6.95 BB	NA	N
Iron	1 / 1	42.5 BB	NA	N
Lead	1 / 1	1.63 BB	NA	N
Magnesium	1 / 1	1860 BB	NA	N
Manganese	1 / 1	1850	NA	Y
Potassium	1 / 1	1870 BB	NA	N
Sodium	1 / 1	7630 BB	NA	N
Zinc	1 / 1	28.8	NA	Y

Notes:
ug/L = Micrograms per liter
NA = Not applicable
BB = Less than background concentration
[1] From March 1993 sampling record
[2] Unfiltered samples from monitoring well SHL-15
[3] Filtered samples from monitoring well SHL-15

TABLE 6-8

SUMMARY STATISTICS FOR FISH TISSUE ANALTYE CONCENTRATIONS[1]

BLUEGILLS (WHOLE FISH)

PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT

FEASIBILITY STUDY FOR GROUP 1A SITES

FORT DEVENS, MA

ANALTYE	FREQUENCY OF DETECTION	MINIMUM CONCENTRATION	MAXIMUM CONCENTRATION	ARITHMETIC MEAN
Pesticides (ug/kg)				
DDE	2/5	21	29	12.92
Inorganics (mg/kg)				
Aluminum	5/5	1.6	4.5	2.58
Arsenic	1/5	1.3	1.3	0.331
Barium	5/5	1.3	4.4	2.76
Calcium	5/5	23300	48800	31940
Chromium	5/5	0.48	0.93	0.656
Cobalt	4/5	0.1	0.16	0.108
Copper	5/5	0.44	0.6	0.506
Iron	5/5	42.4	130	79.72
Lead	1/5	0.16	0.16	0.072
Magnesium	5/5	496	754	568
Manganese	5/5	39.1	94.7	63.2
Mercury	5/5	0.19	0.54	0.368
Selenium	5/5	0.42	0.67	0.55
Sodium	5/5	1480	2290	1794
Thallium	1/5	0.1	0.1	0.06
Zinc	5/5	22.2	29.6	25.02

Notes:

[1] Table inlcudes detected analytes only. Shaded analytes are considered landfill-related.

All detected analytes were included as COPCs.

TABLE 6-9

SUMMARY STATISTICS FOR FISH TISSUE ANALTYE CONCENTRATIONS[1]

BULLHEAD AND BASS (FILLETS)

PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT

FEASIBILITY STUDY FOR GROUP 1A SITES

FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MINIMUM CONCENTRATION	MAXIMUM CONCENTRATION	ARITHMETIC MEAN
Pesticides (ug/kg)				
DDE	2/10	15	31	9.6675
Inorganics (mg/kg)				
Arsenic	2/10	0.09	0.15	0.0497
Calcium	10/10	82.8	627	170.615
Chromium	2/10	0.19	0.24	0.123
Cobalt	2/10	0.11	0.11	0.056
Copper	10/10	0.08	0.24	0.174
Iron	10/10	1.7	27	8.195
Magnesium	10/10	252	344	279.15
Manganese	1/10	0.3	0.3	0.163
Mercury	9/10	0.12	4	1.144
Selenium	8/10	0.11	0.2	0.125
Sodium	10/10	283	509	420.85
Zinc	10/10	3.4	6.1	4.48

Notes:

[1] Table includes detected analytes only. Shaded analytes are considered landfill-related.

All detected analytes were included as COPCs.

TABLE 6-10
SUMMARY STATISTICS FOR SHALLOW SEDIMENT[1]
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	CONCENTRATION MEAN (ug/g)	CONCENTRATION MAXIMUM (ug/g)	COPC (Y/N)
ORGANICS				
acetone	9/13	0.19	0.55	N
methylene chloride	11/13	0.05	0.12	N
2-butanone	5/13	0.04	0.13	N
benzo(a)anthracene	1/13	0.22	1.1	Y
chrysene	1/13	0.32	1.5	Y
fluoranthene	1/13	0.5	3.4	Y
naphthalene	1/13	0.32	1.6	Y
phenanthrene	1/13	0.38	2.5	Y
pyrene	3/13	0.97	4.35	Y
DDE	6/41	0.05	1.3	Y
DDD	4//41	0.07	1.8	Y
DDT	1/41	0.03	0.13	Y
heptachlor	2/41	0.006	0.092	N
INORGANICS[2]				
aluminum	41/41	7,938	24,000	Y
arsenic	41/41	467	3,200	Y
barium	38/41	108	344	Y
beryllium	8/41	0.53	2.72	Y
cadmium	13/41	9.8	60	Y
calcium	39/41	8,074	20,100	Y
cobalt	8/41	5.8	58.7	Y
chromium	38/41	1,987	10,000	Y
copper	30/41	39.7	132	Y
iron	41/41	36,314	330,000	Y
lead	40/41	125	632	Y
magnesium	36/41	1,629	6,900	Y
manganese	37/41	2,639	54,800	Y
mercury	37/41	18.2	130	Y
nickel	25/41	23	79.3	Y
potassium	17/41	435	2,350	Y
selenium	12/41	1.95	6.6	Y
sodium	35/41	1,113	2,870	Y
vanadium	15/41	24.6	166	Y
zinc	17/41	88.6	403	Y

Notes:

[1]Based on sediment samples SE-SHL-01 through SE-SHL-13 (April 1993 RI) and SHD-92-01 through SHD-92-28 at depths of less than 1 foot.

[2]Shaded analytes are considered landfill-related.

TABLE 6–11
CHEMICALS OF POTENTIAL CONCERN[1] IN HUMAN HEALTH RISK ASSESSMENT
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHEMICAL OF POTENTIAL CONCERN	FISH TISSUE	SEDIMENT	GROUNDWATER		
			WELL GROUP 1	WELL GROUP 3	WELL GROUP 4
Inorganics					
Aluminum	X	X	X		
Antimony			X		
Arsenic	X	X	X	X	X
Barium	X	X	X		
Beryllium		X			
Calcium	X	X	X	X	X
Cadmium		X			
Chromium	X	X	X		
Cobalt	X	X	X		
Copper	X	X	X		
Iron	X	X	X		
Lead	X	X	X	X	
Magnesium	X	X	X		
Manganese	X	X	X	X	X
Mercury	X	X			
Nickel		X	X		
Potassium		X	X		X
Selenium	X	X			
Sodium	X	X	X	X	
Thallium	X				
Vanadium		X	X		
Zinc	X	X	X		X

TABLE 6-11
CHEMICALS OF POTENTIAL CONCERN[1] IN HUMAN HEALTH RISK ASSESSMENT
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHEMICAL OF POTENTIAL CONCERN	FISH TISSUE	SEDIMENT	GROUNDWATER		
			WELL GROUP 1	WELL GROUP 3	WELL GROUP 4
VOCs					
Benzene			X		
Chloroethane			X		
Chloroform			X		
1,1-Dichloroethane			X		
1,2-Dichloroethane			X		
1,2-Dichloroethene (cis & trans)			X		
1,2-Dichloropropane			X		
Trichlorofluoromethane					X
SVOCs					
Dichlorobenzenes			X		
Benzo(a)anthracene		X			
Chrysene		X			
Fluoranthene		X			
Naphthalene		X			
Phenanthrene		X			
Pyrene		X			
Pesticides/PCBs					
DDD		X			
DDE	X	X			
DDT		X			

[1] Shaded chemicals are considered to be landfill-related COPCs.

TABLE 6–12
EXPOSURE PARAMETER VALUES
PATHWAY: GROUNDWATER INGESTION AND CONTACT DURING SHOWERING
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

PARAMETER	RECEPTOR	CASE	PARAMETER VALUE	SOURCE	COMMENTS
Water Concentration	Adult/Child	Average	Average concentration	–	–
	Adult/Child	RME	Maximum concentration	–	–
Ingestion Rate	Adult	Average/RME	2 liters/day	Standard Default[1]	90th percentile
	Child	Average/RME	0.5 liters/day	Exposure Factors (Table 2–4)[2]	Mean, ages 5–9
Surface Area (SA) Exposed	Adult	Average/RME	19,400 cm^2	Exposure Factors (Table 4–1)	Mean SA, males
	Child	Average/RME	4545.3 cm^2–yr/kg	See Appendix V	Represents normalized surface area and total body
Body Weight	Adult	Average/RME	70 kg	Standard Default	Average, adult
	Child	Average/RME	16 kg	Exposure Factors (Table 5–3)	Average, ages 3–6
Shower/Bath Exposure Time	Adult	Average/RME	0.2 hours/day	RAGs[3] (Exhibit 6–16)	90th percentile
	Child	Average/RME	0.2 hours/day	RAGs[3] (Exhibit 6–16)	90th percentile
Exposure Frequency	Adult	Average/RME	350 days/year	Standard Default	–
	Child	Average/RME	350 days/year	Standard Default	–
Exposure Duration	Adult	Average/RME	30 years	RAGs (Exhibit 6–11)	90th percentile; national upper bound time at one residence
	Child	Average/RME	5 years	–	Length of time in age range
Averaging Time (cancer)	Adult	Average/RME	70 years	RAGs (Exhibit 6–11)	Lifetime by convention
	Child	Average/RME	70 years	RAGs (Exhibit 6–11)	Lifetime by convention
Averaging Time (non–cancer)	Adult	Average/RME	30 years	RAGs (Exhibit 6–11)	AT = ED
	Child	Average/RME	5 years	RAGs (Exhibit 6–11)	AT = ED

Notes:
RME = Reasonable Maximum Exposure
[1]USEPA Standard Default Exposure Factors (USEPA. 1991b)
[2]USEPA Exposure Factors Handbook (USEPA, 1989b)
[3]USEPA Risk Assessment Guidance for Superfund (RAGs) (USEPA.1989f)

TABLE 6-13
EXPOSURE PARAMETER VALUES
PATHWAY: INHALATION OF VOCs DURING SHOWERING
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

PARAMETER	RECEPTOR	CASE	PARAMETER VALUE	SOURCE	COMMENTS
Air Concentration	Adult	Average/RME	Modeled	–	See Appendix L
	Child	Average/RME	Modeled	–	See Appendix L
Exposure Time	Adult	Average/RME	0.2 hours/day	RAGs[1] (Exhibit 6-16)	90th percentile
	Child	Average/RME	0.2 hours/day	RAGs[1] (Exhibit 6-16)	90th percentile
Exposure Frequency	Adult	Average/RME	350 days/year	Standard Default[2]	
	Child	Average/RME	350 days/year	Standard Default	
Exposure Duration	Adult	Average/RME	30 years	RAGs (Exhibit 6-16)	90th percentile; national upper bound time at one residence
	Child	Average/RME	5 years	–	Length of time in age range
Averaging Time (cancer)	Adult	Average/RME	70 years	RAGs (Exhibit 6-16)	Lifetime by convention
	Child	Average/RME	70 years	RAGs (Exhibit 6-16)	Lifetime by convention
Averaging Time (non-cancer)	Adult	Average/RME	30 years	RAGs (Exhibit 6-16)	AT = ED
	Child	Average/RME	5 years	RAGs (Exhibit 6-16)	AT = ED

Notes:
RME = Reasonable Maximum Exposure
[1] USEPA Risk Assessment Guidance for Superfund (RAGS) (USEPA, 1989f)
[2] USEPA Standard Default Exposure Factors (USEPA, 1991b)

TABLE 6-14
EXPOSURE PARAMETER VALUES
PATHWAY: INGESTION OF FISH
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

PARAMETER	RECEPTOR	CASE	PARAMETER VALUE	SOURCE	COMMENTS
Fish Tissue Concentration	Adult/Child	Average	Average Concentration	–	–
	Adult/Child	RME	Maximum Concentration	–	–
Fish Ingestion Rate	Adult	Average/RME	54 grams/day	Standard Default[1]	Average, adult
	Child	Average/RME	16.5 grams/day	Exposure Factors (Table 2-15)[2]	95th percentile, ages 0-9
Fraction Ingested from Source	Adult	Average/RME	0.5	Assumption	–
	Child	Average/RME	0.5	Assumption	–
Body Weight	Adult	Average/RME	70 kg	Standard Default	Average, adult
	Child	Average/RME	16 kg	Exposure Factors (Table 5-3)	Average, ages 3-6
Exposure Frequency	Adult	Average/RME	350 days/year	Standard Default	–
	Child	Average/RME	350 days/year	Standard Default	–
Exposure Duration	Adult	Average/RME	30 years	Standard Default (Table 1)	90th percentile; national upper bound time at one residence
	Child	Average/RME	5 years	–	Length of time in age range
Averaging Time (cancer)	Adult	Average/RME	70 years	RAGS (Exhibit 6-17)[3]	Lifetime by convention
	Child	Average/RME	70 years	RAGS (Exhibit 6-17)	
Averaging Time (non-cancer)	Adult	Average/RME	30 years	RAGS (Exhibit 6-17)	AT = ED
	Child	Average/RME	5 years	RAGS (Exhibit 6-17)	AT = ED

Notes:
RME = Reasonable Maximum Exposure
[1]USEPA Standard Default Exposure Factors (USEPA, 1991b)
[2]USEPA Exposure Factors Handbook (USEPA, 1989b)
[3]USEPA Risk Assessment Guidance for Superfund (RAGs) (USEPA,1989f)

TABLE 6–15
EXPOSURE PARAMETER VALUES
PATHWAY: SEDIMENT INGESTION AND CONTACT
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

PARAMETER	RECEPTOR	CASE	PARAMETER VALUE	SOURCE	COMMENTS
Sediment Concentration	Adolescent	Average RME	Average Concentration Maximum Concentration	– –	
Ingestion Rate	Adolescent	Average/RME	100 mg/day	Standard Default[1]	Upper–bound value for individual > 6 years of age
Fraction Ingested	Adolescent	Average/RME	100%	Assumption	–
Soil Adherence Factor	Adolescent	Average/RME	0.5 mg/cm^2	Dermal Exposure (Table 8–6)[2]	Between central and upper–bound value in range
Surface Area Exposed	Adolescent	Average/RME	848.6 cm^2–yr/kg	See Appendix V	Represents normalized surface area and 25% of total body surface area
Body Weight	Adolescent	Average/RME	42 kg	Exposure Factors (Table 5–3)[3]	Average, ages 6–16
Exposure Frequency	Adolescent (current use) Adolescent (future use)	Average/RME Average/RME	26 days/year 100 days/year	Assumption Assumption	1 day/week, May through October More frequent exposure based on future residential land use
Exposure Duration	Adolescent	Average/RME	10 years	–	Length of time in age range
Averaging Time (cancer)	Adolescent	Average/RME	70 years	RAGS (Exhibit 6–15)[4]	Lifetime by convention
Averaging Time (non–cancer)	Adolescent	Average/RME	10 years	RAGS (Exhibit 6–15)	AT = ED

Notes:
RME = Reasonable Maximum Exposure
[1]USEPA Standard Default Exposure Factors (USEPA, 1991b)
[2]USEPA Dermal Exposure Assessment: Principles and Applications (USEPA, 1992d)
[3]USEPA Exposure Factors Handbook (USEPA, 1989b)
[4]USEPA Risk Assessment Guidance for Superfund (RAGs) (USEPA.1989f)

TABLE 6–16
COMPARISON OF USEPA AND MADEP EXPOSURE ASSUMPTIONS
IN THE RI RISK ASSESSMENT [1]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE PATHWAY		USEPA	MADEP
Groundwater Ingestion and Contact (While Showering) – Child			
	Body Weight:	16 kg	10 kg
	Ingestion Rate:	0.5 L/day	1 L/day
	Inhalation Rate:	0.6 m^3/hr (all ages)	0.83 m^3/hr adult 0.42 m^3/hr child
Fish Ingestion – Child			
	Body Weight:	16 kg	10 kg
	Ingestion Rate:	54 g/day	20 g/day
Sediment Contact and Ingestion – Adolescent			
	Ingestion Rate:	100 mg/day	50 mg/day

Note:
[1] *Only exposure assumptions that differ between* USEPA *and* MADEP, *for the exposure scenarios to be evaluated in this supplemental* RA, are shown here.

TABLE 6-17
COMPARISON OF USEPA AND MADEP RISK ESTIMATES FROM THE RI RISK ASSESSMENT[1]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE PATHWAY	USEPA		MADEP	
	CANCER	NONCANCER	CANCER	NONCANCER
Groundwater – Child–Average Case:				
Ingestion	4.92E – 4	13	1.57E – 3	45.4
Direct Contact	4.14E – 6	0.0413	6.6E – 6	0.0665
Inhalation of VOCs	2.46E– 6	0.00327	2.7E – 6	0.00365
Source:	Table N–20	Table N–20	Table S–21	Table S–21
Fish Ingestion – Child–Average Case:				
	4.02E – 4	13.5	2.38E – 4	8.03
Source:	Table N–4	Table N–4	Table S–13	Table S–13
Sediment (West Side) – Adolescent – Average Case:				
Ingestion	5.98E – 5	0.811	2.99E – 5	0.407
Source:	Table N–10	Table N–10	Table S–16	Table S–16

Note:
[1] In Appendices N and S of the RI Risk Assessment (April 1993).

TABLE 6-18
ORAL DOSE/RESPONSE INFORMATION FOR CARCINOGENIC EFFECTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHEMICAL	WEIGHT OF EVIDENCE	SLOPE FACTOR $[(mg/kg/day)^{-1}]$	SOURCE	TEST SPECIES	EXPOSURE ROUTE	TUMOR TYPE	STUDY SOURCE
VOCs							
Benzene	A	2.90E-02	IRIS	Human	Inhalation	Leukemia	IRIS
1,2-Dichloroethane	B2	9.10E-02	IRIS	Rat	Oral-gavage	Hemangiosarcoma	IRIS
1,2-Dichloropropane	B2	6.80E-02	HEAST	Mouse	Oral-gavage	Liver	HEAST
SVOCs							
Dichlorobenzene	B2	2.40E-02	HEAST (1)	Mouse	Oral-gavage	Liver	HEAST
Benzo(a)anthracene	B2	7.30E+00	(2)	Mouse	Oral-diet	Stomach	IRIS
Chrysene	B2	7.30E+00	(2)	Mouse	Oral-diet	Stomach	IRIS
PESTICIDES/PCBs							
DDD	B2	2.40E-01	IRIS	Mouse	Oral-diet	Liver	IRIS
DDE	B2	3.40E-01	IRIS	Mouse/hamster	Oral-diet	Liver	IRIS
DDT	B2	3.40E-01	IRIS	Mouse/rat	Oral-diet	Liver	IRIS
INORGANICS							
Arsenic	A	1.75E+00	IRIS (3)	Human	Oral-drinking water	Skin	IRIS
Beryllium	B2	4.30E+00	IRIS	Rat	Oral-drinking water	Total	IRIS
Cadmium	D	NE					
Lead	B2	NE					

Notes:
NE = Not Evaluated
Integrated Risk Information System (IRIS) on-line database search, current as of December 1993.
Health Effects Assessment Summary Tables (HEAST), current as of July 1993.
(1) The ingestion slope factor for 1,4-dichlorobenzene was used as a surrogate for the dichlorobenzenes.
(2) The ingestion slope factor for benzo(a)pyrene was used as a surrogate for all PAHs classified as A or B carcinogens and for which a chemical-specific slope factor was not available.
(3) The ingestion slope factor for arsenic has been calculated from the drinking water unit risk of 5.00E-05 per(ug/L).

Weight of Evidence (route-specific):
A = Human carcinogen
B = Probable human carcinogen (B1 = limited human evidence; B2 = sufficient human evidence)
C = Possible human carcinogen
D = Not classifiable as to human carcinogenicity

TABLE 6-19
ORAL DOSE/RESPONSE DATA FOR NONCARCINOGENIC EFFECTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHEMICAL	CHRONIC ORAL RfD (mg/kg-day)	SOURCE	SUBCHRONIC ORAL RfD (1) (mg/kg-day)	SOURCE	STUDY TYPE	CONFIDENCE LEVEL	CRITICAL EFFECT	TEST ANIMAL	CHRONIC RfD UNCERTAINTY FACTOR	STUDY SOURCE
VOCs										
1,1-Dichloroethane	1.00E-01	HEAST (2)	1.00E+00	HEAST	Inhalation	Low	No effects observed	Rat	1000 H,A,S	HEAST
1,2-Dichloroethane	3.00E-01	ECAO	ND							
1,2-Dichloroethylene (total)	9.00E-03	(3)	9.00E-03	(3)	Oral-drinking water	Medium	Liver lesions	Rat	1000 H,A,L	IRIS
cis-1,2-Dichloroethene	1.00E-02	HEAST	1.00E-01	HEAST	Gavage		Decreased hematocrit and hemoglobin	Rat	3000	HEAST
1,2-Dichloropropane	ND		ND							
Chloroethane	2.00E-02	ECAO	ND							
Trichlorofluoromethane	3.00E-01	IRIS	7.00E-01	HEAST	Gavage	Medium	Increased mortality	Rat, Mouse	1000 H,A,L	IRIS
Benzene	ND		ND							
SVOCs										
Dichlorobenzenes	9.00E-02	(4)	9.00E-01	IRIS	Oral-gavage	Low	No adverse effects observed	Rat	1000 H,A,D	IRIS
Benzo(a)anthracene	4.00E-02	(5)	ND							
Chrysene	4.00E-02	(5)	ND							
Fluoranthene	4.00E-02	IRIS	4.00E-01	HEAST	Oral-gavage	Low	Increased liver weight, clinical effects	Mouse	3000 H,A,S,D	IRIS
Naphthalene	4.00E-02	(6)	ND	(6)	Gavage		Decreased body weight gain	Rat	1000	HEAST
Phenanthrene	4.00E-02	(5)	ND							
Pyrene	3.00E-02	IRIS	3.00E-01	HEAST	Oral-gavage	Low	Renal tubular pathology	Mouse	3000 H,A,S,D	IRIS
PESTICIDES/PCBs										
DDD	5.00E-04	(7)	5.00E-04	(7)						
DDE	5.00E-04	(7)	5.00E-04	(7)						
DDT	5.00E-04	IRIS	5.00E-04	HEAST	Oral-diet	Medium	Liver lesions	Rat	100 H,A	IRIS
INORGANICS										
Aluminum	ND		ND							
Antimony	4.00E-04	IRIS	4.00E-04	HEAST	Oral-drinking water	Low	Reduced lifespan	Rat	1000 H,A,L	IRIS
Arsenic	3.00E-04	IRIS	3.00E-04	HEAST	Oral-drinking water	Medium	Hyperpigmentation, keratosis	Human	3 D	IRIS
Barium	7.00E-02	IRIS	7.00E-02	HEAST	Oral-drinking water	Medium	Elevated blood pressure	Human	3 H	IRIS
Beryllium	5.00E-03	IRIS	5.00E-03	HEAST	Oral-drinking water	Low	No effects observed	Rat	100 H,A	IRIS
Cadmium (food)	1.00E-03	IRIS	ND		Oral-diet	High	Proteinuria	Human	10 H	IRIS
Cadmium (water)	5.00E-04	IRIS	ND		Oral-drinking water	High	Proteinuria	Human	10 H	IRIS
Calcium	ND		ND							
Chromium III	1.00E+00	IRIS	1.00E+00	HEAST	Oral-diet	Low	No effects observed	Rat	100 H,A	IRIS
Chromium VI	5.00E-03	IRIS	2.00E-02	HEAST	Oral-drinking water	Low	No effects observed	Rat	500 H,A,S	IRIS
Cobalt	ND		ND							
Copper	ND		ND							
Iron	ND		ND							
Lead	ND		ND							
Magnesium	ND		ND							

TABLE 6-19
ORAL DOSE/RESPONSE DATA FOR NONCARCINOGENIC EFFECTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHEMICAL	CHRONIC ORAL RfD (mg/kg-day)	SOURCE	SUBCHRONIC ORAL RfD (1) (mg/kg-day)	SOURCE	STUDY TYPE	CONFIDENCE LEVEL	CRITICAL EFFECT	TEST ANIMAL	CHRONIC RfD UNCERTAINTY FACTOR	STUDY SOURCE
Manganese (food)	1.40E-01	IRIS	1.40E-01	HEAST	Oral-diet	NA	No effects observed	Human	1	IRIS
Manganese (water)	5.00E-03	IRIS	5.00E-03	HEAST	Oral-drinking water	NA	CNS effects	Human	1	IRIS
Mercury	3.00E-04	HEAST (2,8)	3.00E-04	HEAST	Oral-gavage	Low	Kidney effects	Rat	1000 H,A,D	HEAST
Nickel	2.00E-02	IRIS (9)	2.00E-02	HEAST	Oral-diet	Medium	Decreased body, organ weights	Rat	300 H,A,D	IRIS
Potassium	ND		ND							
Selenium	5.00E-03	IRIS	5.00E-03	HEAST	Oral-diet	High	Selenosis	Human	3 H	IRIS
Sodium	ND		ND							
Thallium	7.00E-05	IRIS (10)	7.00E-04	HEAST	Oral-gavage	Low	No effects observed	Rat	3000 H,A,S,D	IRIS
Vanadium	7.00E-03	HEAST (2)	7.00E-03	HEAST	Oral-drinking water	Low	No effects observed	Rat	100 H,A	HEAST
Zinc	3.00E-01	IRIS	3.00E-01	HEAST	Oral-diet supplemen	Medium	Decrease in ESOD activity	Human	3 S	IRIS

Notes:
ND = No Data
NA = Not Applicable
Integrated Risk Information System (IRIS) on-line database search, current as of December 1993.
Health Effects Assessment Summary Tables (HEAST), current as of July 1993.
USEPA Environmental Criteria and Assessment Office (ECAO); Cincinatti, Ohio.
(1) The chronic RfD will be used as a surrogate for compounds without subchronic RfDs.
(2) This value is currently listed in HEAST, but has been withdrawn from IRIS and is under review.
(3) The values for 1,1-dichloroethylene have been used as surrogates for 1,2-dichloroethylene (total) based on analogy.
(4) The ingestion RfD for 1,2-dichlorobenzene has been used as a surrogate for the dichlorobenzenes.
(5) The RfD for naphthalene is used as a surrogate for PAHs without assigned RfDs.
(6) The values for naphthalene have been withdrawn from IRIS and HEAST and are currently under review.
(7) The RfD for DDT is used as a surrogate.
(8) This mercury value is specific for inorganic mercury.
(9) The ingestion RfD values for nickel are based on nickel, soluble salts.
(10) The ingestion RfD values for thallium are based on analogy to thallium sulfate, correcting for molecular weight differences.

Uncertainty factors:
H = Variation in human sensitivity
A = Animal to human extrapolation
S = Extrapolation from subchronic to chronic NOAEL
L = Extrapolation from LOAEL to NOAEL
D = Inadequate data

TABLE 6-20

INHALATION DOSE/RESPONSE DATA FOR CARCINOGENIC EFFECTS

SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT

FEASIBILITY STUDY FOR GROUP 1A SITES

FORT DEVENS, MA

CHEMICAL	WEIGHT OF EVIDENCE	UNIT RISK $(ug/m^3)^{-1}$	TEST SPECIES	STUDY TYPE	TUMOR TYPE	SOURCE
1,1-Dichloroethane	C	ND				IRIS
1,2-Dichloroethane	B2	2.6E-05	Rat	Gavage	Hemangiosarcomas	IRIS
Benzene	A	8.3E-06	Human	Inhalation	Leukemia	IRIS

Notes:

ND = Not determined

ug = microgram

m^3 = cubic meter

Integrated Risk Information System (IRIS) on-line database search, current as of December 1993.

Weight of Evidence: A = Human carcinogen

B = Probable human carcinogen (B1 = limited evidence in humans;

B2 = sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)

C = Possible human carcinogen

TABLE 6-21
INHALATION DOSE/RESPONSE DATA FOR NONCARCINOGENIC EFFECTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHEMICAL	CHRONIC RfC (mg/m^3)	SOURCE	SUBCHRONIC RfC (mg/m^3)	SOURCE	STUDY TYPE	CONFIDENCE LEVEL	CRITICAL EFFECT	TEST ANIMAL	UNCERTAINTY FACTOR	STUDY SOURCE
VOCs										
1,1-Dichloroethane	5.00E-01	HEAST (1)	5.00E+00	HEAST	Inhalation	Low	Kidney damage	Cat	1000 H,A,S	HEAST
1,2-Dichloroethane	1.00E-02	ECAO (2)	ND							
1,2-Dichloroethylene (total)	ND		ND							
1,2-Dichloropropane	4.00E-03	IRIS	1.30E-02	HEAST	Inhalation	Medium	Hyperplasia of nasal mucosa	Rat	300 H,A,S,L	IRIS
Benzene	2.00E-04	ECAO (2)	ND							
Chloroethane	1.00E+01	IRIS	1.00E+01	HEAST	Inhalation	Medium	Delayed fetal ossification	Mouse	300 H,A,S,D	IRIS
Trichlorofluoromethane	7.00E-01	HEAST	7.00E+00	HEAST	Inhalation		Increased BUN, lung inflammation	Dog	10000 H,A,S,L	
SVOCs										
Dichlorobenzenes	2.00E-01	(3)(4)	2.00E+00	(3)(4)	Inhalation	Low	Liver, kidney effects	Rat	100 H,A	HEAST

Notes:
ND = No Data
NA = Not Applicable
Integrated Risk Information System (IRIS) on-line database search, current as of December 1993.
Health Effects Assessment Summary Tables (HEAST), current as of July 1993.
USEPA Environmental Criteria and Assessment Office (ECAO); Cincinatti, Ohio.
(1) This value is currently listed in HEAST, but has been withdrawn from IRIS and is under review.
(2) Inhalation RfC was calculated from the inhalation RfD, by multiplying by 70 kg body weight and dividing by 20 m^3/day inhalation rate.
(3) The inhalation RfC for 1,2-dichlorobenzene has been used as a surrogate for the dichlorobenzenes.
(4) This value has been recently withdrawn from HEAST and is currently under review.

Uncertainty factors:
H = Variation in human sensitivity
A = Animal to human extrapolation
S = Extrapolation from subchronic to chronic NOAEL
L = Extrapolation from LOAEL to NOAEL
D = Inadequate data

TABLE 6-22
DERMAL DOSE/RESPONSE DATA
FOR CARCINOGENIC EFFECTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHEMICAL	WEIGHT OF EVIDENCE	ORAL SLOPE FACTOR [a] $[(mg/kg/day)^{-1}]$	ABSORPTION EFFICIENCY	REFERENCE	ADJUSTED SLOPE FACTOR $[(mg/kg/day)^{-1}]$
VOCs					
1,2-Dichloroethane	B2	9.10E-02	100%	Reitz et al., 1980	9.10E-02
1,2-Dichloropropane	B2	6.80E-02	100%	ATSDR, 1989c	6.80E-02
Benzene	A	2.90E-02	NA	[b]	2.90E-02
SVOCs					
Benzo(a)Anthracene	B2	7.30E+00	91%	[c]	8.02E+00
Chrysene	B2	7.30E+00	91%	[c]	8.02E+00
Dichlorobenzenes	B2	2.40E-02	100%	ATSDR, 1989b	2.40E-02
Pesticides and PCBs					
DDD	B2	2.40E-01	20%	[d]	1.20E+00
DDE	B2	3.40E-01	20%	[d]	1.70E+00
DDT	B2	3.40E-01	20%	Siebert, 1976	1.70E+00
Inorganics					
Arsenic	A	1.75E+00	98%	Vahter, 1983	1.79E+00
Beryllium	B2	4.30E+00	1%	Owen, 1990	4.30E+02
Cadmium	ND	ND	NA		ND
Lead	B2	ND	NA		ND

Notes:
ND = Not Determined
NA = Not Applicable
[a] For documentation concerning oral slope factors, refer to Table 6-18.
[b] This cancer slope factor is based on absorbed dose. Therefore, no adjustment of this toxicity value is necessary.
[c] The oral absorption of this compound is assumed to be identical to that of benzo(a)pyrene (Hecht et al., 1979), based on structural analogy.
[d] The oral absorption of this compound is assumed to be identical to that of DDT (Siebert, 1976), based on structural analogy.

Weight of Evidence (route-specific):
A = Human carcinogen
B = Probable human carcinogen (B1 = limited human evidence; B2 = sufficient human evidence)

TABLE 6-23
DERMAL DOSE/RESPONSE DATA
FOR NONCARCINOGENIC EFFECTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHEMICAL	CHRONIC ORAL RfD [a] (mg/kg-day)	SUBCHRONIC ORAL RfD [a] (mg/kg-day)	ABSORPTION EFFICIENCY	REFERENCE	ADJUSTED CHRONIC RfD (mg/kg-day)	ADJUSTED SUBCHRONIC RfD (mg/kg-day)
VOCs						
1,1-Dichloroethane	1.00E-01	1.00E+00	100%	[b]	1.00E-01	1.00E+00
1,2-Dichloroethane	3.00E-01	ND	100%	Reitz et al., 1980	3.00E-01	ND
cis-1,2-Dichloroethene	1.00E-02	1.00E-01	100%	[c]	1.00E-02	1.00E-01
trans-1,2-Dichlorethene	2.00E-02	2.00E-01	100%	[c]	2.00E-02	2.00E-01
1,2-Dichloroethene (total)	9.00E-03	9.00E-03	100%	[c]	9.00E-03	9.00E-03
1,2-Dichloropropane	ND	ND	NA		ND	ND
Benzene	ND	ND	NA		ND	ND
Trichlorofluoromethane	3.00E-01	7.00E-01	100%	[d]	3.00E-01	7.00E-01
Chloroethane	2.00E-02	ND	100%	[d]	2.00E-02	ND
SVOCs						
Dichlorobenzenes	9.00E-02	9.00E-01	100%	ATSDR, 1989b	9.00E-02	9.00E-01
Benzo(a)anthracene	4.00E-02	4.00E-02	100%	[e]	4.00E-02	4.00E-02
Chrysene	4.00E-02	4.00E-02	100%	[e]	4.00E-02	4.00E-02
Fluoranthene	4.00E-02	4.00E-01	91%	[f]	3.64E-02	3.64E-01
Naphthalene	4.00E-02	4.00E-02	100%	[e]	4.00E-02	4.00E-02
Phenanthrene	4.00E-02	4.00E-02	100%	[e]	4.00E-02	4.00E-02
Pyrene	3.00E-02	3.00E-01	91%	[f]	2.73E-02	2.73E-01
Pesticides/PCBs						
DDD	5.00E-04	5.00E-04	20%	[g]	1.00E-04	1.00E-04
DDE	5.00E-04	5.00E-04	20%	[g]	1.00E-04	1.00E-04
DDT	5.00E-04	5.00E-04	20%	Siebert, 1976	1.00E-04	1.00E-04
Inorganics						
Aluminum	ND	ND	NA		ND	ND
Antimony	4.00E-04	4.00E-04	1%	ATSDR, 1991a	4.00E-06	4.00E-06
Arsenic	3.00E-04	3.00E-04	98%	Vahter, 1983	2.94E-04	2.94E-04
Barium	7.00E-02	7.00E-02	7%	ATSDR, 1991b	4.90E-03	4.90E-03
Beryllium	5.00E-03	5.00E-03	1%	Owen, 1990	5.00E-05	5.00E-05
Calcium	ND	ND	NA		ND	ND

TABLE 6-23
DERMAL DOSE/RESPONSE DATA
FOR NONCARCINOGENIC EFFECTS
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHEMICAL	CHRONIC ORAL RfD [a] (mg/kg-day)	SUBCHRONIC ORAL RfD [a] (mg/kg-day)	ABSORPTION EFFICIENCY	REFERENCE	ADJUSTED CHRONIC RfD (mg/kg-day)	ADJUSTED SUBCHRONIC RfD (mg/kg-day)
Cadmium						
Dietary exposure	1.00E-03	ND	1%	McLellan et al., 1978	1.00E-05	ND
Drinking water exposure	5.00E-04	ND	7%	McLellan et al., 1978	3.50E-05	ND
Chromium						
Trivalent	1.00E+00	1.00E+00	10%	ATSDR, 1989a	1.00E-01	1.00E-01
Hexavalent	5.00E-03	2.00E-02	11%	Ogawa, 1976	5.50E-04	2.20E-03
Cobalt	ND	ND	NA		ND	ND
Copper	ND	ND	NA		ND	ND
Iron	ND	ND	NA		ND	ND
Lead	ND	ND	NA		ND	ND
Magnesium	ND	ND	NA		ND	ND
Manganese						
Dietary exposure	1.40E-01	1.40E-01	4%	ATSDR, 1991c	5.60E-03	5.60E-03
Drinking water exposure	5.00E-03	5.00E-03	4%	ATSDR, 1991c	2.00E-04	2.00E-04
Mercury	3.00E-04	3.00E-04	20%	Nielsen, 1992	6.00E-05	6.00E-05
Nickel	2.00E-02	2.00E-02	5%	Christenson & Lagesson, 1981	1.00E-03	1.00E-03
Potassium	ND	ND	NA		ND	ND
Selenium	5.00E-03	5.00E-03	60%	Owen, 1990	3.00E-03	3.00E-03
Sodium	ND	ND	NA		ND	ND
Thallium	7.00E-05	7.00E-04	100%	Lie et al., 1960	7.00E-05	7.00E-04
Vanadium	7.00E-03	7.00E-03	3%	ATSDR, 1991d	2.10E-04	2.10E-04
Zinc	3.00E-01	3.00E-01	34%	Sandstrom et al., 1987	1.02E-01	1.02E-01

Notes:
ND = No Data Available
NA = Not Applicable
[a] For documentation concerning chronic and subchronic oral RfDs, refer to Table 6-19.
[b] The oral absorption of 1,1-dichloroethane is assumed to be identical to that of 1,2-dichloroethane, based on structural analogy.
[c] The oral absorption of 1,2-dichloroethylene (cis-, trans-, and mixed isomers) is assumed to be identical to that of 1,1-dichloroethylene (Putcha et al., 1986), based on structural analogy.
[d] VOCs lacking specific absorption information are assumed to have an absorption efficiency of 100%, based on analogy with other VOCs.
[e] The oral absorption of PAHs lacking chemical-specific RfDs is assumed to be identical to that of naphthalene (Chang, 1943).
[f] The oral absorption of PAHs with chemical-specific RfDs is assumed to be identical to that of benzo(a)pyrene (Hecht et al., 1979), based on structural analogy.
[g] The oral absorption of DDE is assumed to be identical to that of DDT (Siebert, 1976), based on structural analogy.

TABLE 6-24
DEFAULT ABSORPTION FRACTIONS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE PATHWAY	COMPOUND	DEFAULT ABSORPTION FRACTIONS		
		DERMAL	INGESTION	INHALATION
Direct Contact with Sediment[1]	VOCs	50%	100%	NA
	SVOCs			
	PAHs	5%	100%	NA
	PCBs	5%	30%	NA
	Pesticides			
	-high sorption to soils (e.g., chlordane, DDD, DDT)	5%	30%	NA
	-low sorption to soils (e.g., lindane, acrolein)	50%	100%	NA
	Inorganics	1%	100% (except lead)	NA
	Lead	1%	30% adults	NA
			50% children (age 1-6)	NA
Ingestion of Groundwater[1]	All Compounds	NA	100%	NA
Ingestion of Fish	All Compounds	NA	100%	NA
Inhalation of VOCs in Shower	All VOCs	NA	NA	100%

Notes:
NA = Not Applicable
[1] Default USEPA Region I Absorption Fractions (USEPA, 1989c)

TABLE 6-25
SUMMARY OF CANCER RISK ESTIMATES
CURRENT LAND USE
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE SCENARIO	ADULT		ADOLESCENT		CHILD		RISK CCONTRIBUTIONS[1] (BY CHEMICAL)
	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	
Ingestion of Bluegills							
Landfill-related COPCs	9.0E-05	4.0E-04	NA	NA	2.0E-05	8.0E-05	Arsenic (99 %)[2]
Total Risk- All COPCs	9.0E-05	4.0E-04	NA	NA	2.0E-05	8.0E-05	
Ingestion of Fillets (bullhead and bass)							
Landfill-related COPCs	1.0E-05	4.0E-05	NA	NA	3.0E-06	9.0E-06	Arsenic (96 %)[2]
Total Risk- All COPCs	1.0E-05	4.0E-05	NA	NA	3.0E-06	1.0E-05	
Sediment Contact							
Landfill-related COPCs	NA	NA	2.0E-05	2.0E-04	NA	NA	Arsenic (100 %)
Total Risk- All COPCs	NA	NA	2.0E-05	2.0E-04	NA	NA	
Total Risk[3]							
Landfill-related COPCs	3E-05	2E-04	NA	NA	3E-06	9E-06	
All COPCs	3E-05	2E-04			3E-06	1E-05	

Notes:

[1]Risk contributions are identified for the receptor showing the greatest risk.

[2]An additional COPC, 4,4'-DDE, presents risks above the USEPA point of departure of $1x10^{-6}$ (at $2x10^{-6}$); this COPC is not thought to be landfill-related and represents 0.4% of risk in bluegills and 4% of the total risk in the fillets.

[3] For an adult, includes ingestion of fillets and sediment contact as an adolescent. For a child, includes ingestion of fillets only.

EPC = Exposure Point Concentration

NA= Not Applicable

TABLE 6–26
SUMMARY OF NONCANCER RISK ESTIMATES
CURRENT LAND USE
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE SCENARIO	ADULT		ADOLESCENT		CHILD		RISK CONTRIBUTIONS[1,2] (BY CHEMICAL)
	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	
Ingestion of Bluegills							
Landfill–related COPCs	0.6	2	NA	NA	0.8	3	Arsenic (0.5,2; skin)[3]
Total Risk – All COPCs	1	3	NA	NA	2	4	
Ingestion of Fillets (bullhead and bass)							
Landfill–related COPCs	0.06	0.2	NA	NA	0.08	0.2	Mercury (2,7; kidney)[4]
Total Risk – All COPCs	1	5	NA	NA	2	7	
Sediment Contact							
Landfill–related COPCs	NA	NA	0.3	3	NA	NA	Arsenic (0.3,2; skin)[5]
Total Risk – All COPCs	NA	NA	0.4	3	NA	NA	
Total Risk[6]							
Landfill–related COPCs	0.06	0.2	0.3	3	0.08	0.2	
All COPCs	1	5	0.4	3	2	7	

Notes:

[1]Hazard quotients for individual chemicals shown in parentheses, at average and maximum EPCs, respectively, for receptor showing greatest risk. Toxicity endpoint of dose/response value shown in parentheses also.

[2]Hazard indices for mixtures have been rounded to one significant figure while a hazard quotient for an individual chemical may have more than one significant figure.

[3]The hazard quotients for three other COPCs were 0.1 or greater: manganese (0.2 and 0.3), mercury (0.6 and 0.9), and thallium (0.4 and 0.7). Only arsenic and manganese are thought to be landfill–related.

[4]The hazard quotient for one other COPC was 0.1 or greater: arsenic (0.08 and 0.3). Mercury is not thought to be landfill–related.

[5]The hazard quotients for three other COPCs were 0.1 or greater: manganese (0.3 and 0.4), cadmium (0.2), mercury (0.1). Only manganese is thought to be landfill–related.

[6] For an adult and child, includes ingestion of fillets only. For an adolescent, includes sediment contact only.

EPC = Exposure Point Concentration

NA = Not Applicable

TABLE 6-27
SUMMARY OF CANCER RISK ESTIMATES
FUTURE LAND USE
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE SCENARIO	ADULT		ADOLESCENT		CHILD		RISK CONTRIBUTIONS[1] (BY CHEMICAL)
	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	
Ingestion of Bluegills							
Landfill-related COPCs	9E-05	4E-04	NA	NA	2E-05	8E-05	Arsenic (99 %)[2]
Total Risk - All COPCs	9E-05	4E-04	NA	NA	2E-05	8E-05	
Ingestion of Fillets (bullhead and bass)							
Landfill-related COPCs	1E-05	4E-05	NA	NA	3E-06	9E-06	Arsenic (96 %)[2]
Total Risk - All COPCs	1E-05	4E-05	NA	NA	3E-06	1E-05	
Sediment Contact							
Landfill-related COPCs	NA	NA	9E-05	6E-04	NA	NA	Arsenic (96 %)[3]
Total Risk - All COPCs	NA	NA	9E-05	6E-04	NA	NA	
Residential Groundwater Use (Well Group 1)							
Unfiltered	4E-04	2E-03	NA	NA	8E-05	3E-04	Arsenic (99 %)[4]
Filtered	3E-04	1E-03	NA	NA	5E-05	2E-04	Arsenic (100 %)
Total Risk[5]							
Unfiltered	5E-04	3E-03	NA	NA	8E-05	3E-04	
Filtered	4E-04	2E-03	NA	NA	5E-05	2E-04	

Notes:

[1] Risk contributions were identified for the receptor showing the greatest risk, and were calculated before rounding off risk estimates for individual chemicals and for the summary risk estimate.

[2] An additional COPC, 4,4'-DDE, presents risks above the USEPA point of departure of $1x10^{-6}$ (at $2x10^{-6}$): this COPC is not thought to be landfill-related and represents 0.4% of the total risk in bluegills and 4% of the total risk in the fillets.

[3] At maximum EPC, three additional COPCs presented cancer risks at or above the USEPA point of departure of $1x10^{-6}$: benzo(a)anthracene ($2x10^{-6}$), chrysene ($2x10^{-6}$), and beryllium ($2x10^{-5}$): these COPCs are not thought to be landfill-related and represent approximately 4% of the total risk.

[4] Two additional COPCs, 1,2-dichloroethane ($6x10^{-6}$) and dichlorobenzenes ($3x10^{-6}$), presents cancer risk above the USEPA point of departure of $1x10^{-6}$, but account for less than 1% of the total risk.

[5] Total risk is calculated for adults who consume COPCs in fillets, contact sediment as adolescents, and use the groundwater from Well Group 1 for ingestion and other domestic purposes. Total risk is calculated for children who consume fillets and use the groundwater from Well Group 1 for ingestion and other domestic purposes.

EPC = Exposure Point Concentration

NA = Not Applicable

TABLE 6-28
SUMMARY OF NONCANCER RISK ESTIMATES
FUTURE LAND USE
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE SCENARIO	ADULT		ADOLESCENT		CHILD		RISK CONTRIBUTIONS[1] (BY CHEMICAL)
	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	
Ingestion of Bluegills							
Landfill-related COPCs	0.6	2	NA	NA	0.8	3	
Total Risk- All COPCs	1	3	NA	NA	2	4	Arsenic (0.5,2; skin)[2]
Ingestion of Fillets (bullhead and bass)							
Landfill-related COPCs	0.06	0.2	NA	NA	0.08	0.2	
Total Risk- All COPCs	1	5	NA	NA	2	7	Mercury (2,7; kidney)[3]
Sediment Contact							
Landfill-related COPCs	NA	NA	1	10	NA	NA	
Total Risk- All COPCs	NA	NA	2	10	NA	NA	Arsenic (1,8), Manganese (0.06,1; CNS effects)[4]
Residential Groundwater Use (Well Group 1)							
Unfiltered	5	20	NA	NA	5	20	Arsenic (2, 8), Manganese (3, 16)[5]
Filtered	4	20	NA	NA	4	20	Arsenic (1,6), Manganese (3,16)
Total Risk[6]							
Landfill-related COPCs:							
Unfiltered	5	20	NA	NA	5	20	
Filtered	4	20	NA	NA	4	20	
All COPCs:							
Unfiltered	6	25	NA	NA	7	27	
Filtered	5	25	NA	NA	6	27	

Notes:

[1]Hazard quotients for individual chemicals shown in parentheses, at average and maximum EPCs, respectively, for receptor showing greatest risk. Toxicity endpoint of dose/response value also shown in parentheses. Hazard indices for mixtures have been rounded to one significant figure while a hazard quotient for an individual chemical may have more than one significant figure.

[2]The hazard quotients for three other COPCs were 0.1 or greater: manganese (0.2 and 0.3), mercury (0.6 and 0.9), and thallium (0.4 and 0.7). Only arsenic and manganese are thought to be landfill-related.

[3]The hazard quotient for one other COPC was 0.1 or greater: arsenic (0.08 and 0.3). Mercury is not thought to be landfill-related.

[4]At maximum concentrations, the hazard quotients for four other COPCs were 0.1 or greater: cadmium (0.7), chromium VI (0.3), mercury (0.5), and vanadium (0.1): these COPCs are not thought to be landfill-related and each hazard quotient is less than the USEPA point of departure of 1.0.

[5]At maximum concentrations, the hazard quotients for three other COPCs were 0.1 or greater: benzene (0.4), vanadium (0.1) and antimony (0.1).

[6]Total risk is calculated for adults and children who consume COPCs in fillets and use the groundwater from Well Group 1 for domestic purposes.

EPC = Exposure Point Concentration

NA= Not Applicable

TABLE 6-29
SUMMARY OF RISKS ASSOCIATED WITH WELL GROUPS 3 and 4
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

RESIDENTIAL GROUNDWATER USE	ADULT				CHILD				RISK CONTRIBUTION (BY CHEMICAL)
	AVERAGE EPC		MAXIMUM EPC		AVERAGE EPC		MAXIMUM EPC		
	CANCER RISK	HI	CANCER RISK	HI	CANCER RISK	HI	CANCER RISK	HI	
Well Group 3									
Unfiltered	3E - 5	1	7E - 5	2	6E - 6	1	1E - 5	3	Arsenic (100%)
Filtered	NA[1]	NA	ND	NC	NA	NA	ND	NC	Manganese (1, 3)[1]
Well Group 4									
Unfiltered	NA	NA	1E - 4	2	NA	NA	2E - 5	3	Arsenic (100%)
Filtered	NA	NA	ND	3	NA	NA	ND	3	Manganese (3)

Notes:

[1] The hazard quotient for one other COPC, arsenic, was 0.1 or greater (at 0.2 and 0.3).

NA = Not applicable.

NC = Not calculated because of a lack of dose/response data.

ND = No carcinogenic compounds detected.

TABLE 6-30
COMPARISON OF FISH EXPOSURE POINT CONCENTRATIONS
TO FDA ACTION LEVELS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FDA ACTION LEVEL		WHOLE FISH (CONCENTRATIONS IN mg/kg) AVERAGE CONCENTRATION	WHOLE FISH (CONCENTRATIONS IN mg/kg) MAXIMUM CONCENTRATION	FILLET (CONCENTRATIONS IN mg/kg) AVERAGE CONCENTRATION	FILLET (CONCENTRATIONS IN mg/kg) MAXIMUM CONCENTRATION
DDE	5	(1)	0.013	0.029	0.0097	0.031
Mercury	1	(2)	0.37	0.54	1.14	4.0

Notes:

COPCs not listed do not have FDA Action Levels

EPCs exceeding action levels are highlighted

ND = Not Detected

(1) In edible portion

(2) Methyl mercury in edible portion

TABLE 6-31
COMPARISON OF GROUNDWATER CONCENTRATIONS TO ARARs
SHEPLEY'S HILL LANDFILL - WELL GROUP 1

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION (ug/L)	ARITHMETIC AVERAGE CONCENTRATION (ug/L)	FEDERAL MCLs (ug/L)	MASS. MCLs (ug/L)	MASS. GUIDELINES (ug/L)	MASS. GROUNDWATER STANDARDS (ug/L)
UNFILTERED SAMPLES							
VOCs							
1,1-Dichloroethane	4/14	4.4	0.86	ND	ND	70	5
1,2-Dichloroethane	5/14	9.9	0.97	5	5	ND	5
1,2-Dichloroethene (total)	6/14	7	1.4	70 (1)	70	ND	70 (1)
1,2-Dichloropropane	1/14	0.52	0.27	5	5	ND	1
Benzene	3/14	1.7	0.51	5	5	ND	5
Chloroethane	1/14	5.5	1.3	ND	ND	ND	ND
SVOCs							
Dichlorobenzenes	1/14	11	5.4	75 (7)	5 (7)	ND	5 (7)
Inorganics							
Aluminum	13/14	75500	4259	50-200(2)	50-200 (6)	ND	ND
Antimony	2/14	3.3	1.7	6	ND	6	ND
Arsenic	12/14	390	101	50	50	ND	50
Barium	13/14	350	47.6	2000	2000	ND	1000
Calcium	14/14	219000	54280	ND	ND	ND	ND
Chromium	5/14	115	9	100	100	ND	50

TABLE 6-31

COMPARISON OF GROUNDWATER CONCENTRATIONS TO ARARs

SHEPLEY'S HILL LANDFILL - WELL GROUP 1

REMEDIAL INVESTIGATION ADDENDUM REPORT

FEASIBILITY STUDY FOR GROUP 1A SITES

FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION (ug/L)	ARITHMETIC AVERAGE CONCENTRATION (ug/L)	FEDERAL MCLs (ug/L)	MASS. MCLs (ug/L)	MASS. GUIDELINES (ug/L)	MASS. GROUNDWATER STANDARDS (ug/L)
Cobalt	1/14	54.6	14	ND	ND	ND	ND
Copper	4/14	92.2	8.6	1300 (3)	1300	ND	1000
Iron	14/14	97400	17608	300 (2)	300 (6)	ND	300
Lead	10/14	66.8	5.2	15 (3)	15	ND	50
Magnesium	14/14	24000	7603	ND	ND	ND	ND
Manganese	14/14	9650	2045	200/50(4/2)	50 (6)	ND	50
Nickel	1/14	177	22.9	100	ND	100	ND
Potassium	13/14	31800	7119	ND	ND	ND	ND
Sodium	14/14	67300	20749	20000 (5)	ND	28000	20000
Vanadium	3/14	79.1	9.4	ND	ND	ND	ND
Zinc	3/14	220	29.4	11000/5000(5/2)	5000 (6)	ND	5000
FILTERED SAMPLES							
Aluminum	1/10	236	NA	50-200(2)	50-200(6)	ND	ND
Antimony	1/10	3.12	2	6	ND	6	ND
Arsenic	6/10	270	71	50	50	ND	50
Barium	10/10	117	30	2000	2000	ND	1000

TABLE 6–31

COMPARISON OF GROUNDWATER CONCENTRATIONS TO ARARs

SHEPLEY'S HILL LANDFILL – WELL GROUP 1

REMEDIAL INVESTIGATION ADDENDUM REPORT

FEASIBILITY STUDY FOR GROUP 1A SITES

FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION (ug/L)	ARITHMETIC AVERAGE CONCENTRATION (ug/L)	FEDERAL MCLs (ug/L)	MASS. MCLs (ug/L)	MASS. GUIDELINES (ug/L)	MASS. GROUNDWATER STANDARDS (ug/L)
Calcium	10/10	175000	37402	ND	ND	ND	ND
Iron	7/10	91600	14427	300 (2)	300 (6)	ND	300
Lead	2/10	1.52	NA	15 (3)	15	ND	50
Magnesium	9/10	19900	4679	ND	ND	ND	ND
Manganese	10/10	9540	1812	200/50(4/2)	50 (6)	ND	50
Potassium	9/10	10600	4127	ND	ND	ND	ND
Sodium	10/10	64600	16934	20000 (5)	ND	28000	20000
Zinc	1/10	25.5	11	11000/5000(5/2)	5000 (6)	ND	5000

Notes:

Shaded line denotes either average or maximum (or both) concentration(s) of analyte exceeds at least one of the ARARs

NA = Not applicable ND = No value available

(1) Value for cis– isomer (lower value of the two isomers)

(2) Secondary maximum contaminant level (SMCL)

(3) Treatment technique

(4) Maximum contaminant level goal (MCLG)

(5) USEPA drinking water equvalency level (DWEL) – A lifetime exposure concentration protective of adverse, noncancer health effects that assumes all exposure is from a drinking water source

(6) Massachusetts SMCL

(7) Value for the p–isomer (lowest of the three isomers).

References:

USEPA, 1993. "Drinking Water Regulations and Health Advisories." Office of Water, Washington, D.C.; May, 1993.

MADEP, 1993. "Drinking Water Standards & Guidelines for Chemicals in Massachusetts Drinking Waters." Office of Research and Standards; Boston, MA; Spring, 1993.

MADEP, 1989. "Guidance for Disposal Site Risk Characterization and Related Phase II Activities – In Support of the Massachusetts Contingency Plan." Appendix C. Office of Research and Standards; Boston, MA; July, 1991 update.

Table 6–32

COMPARISON OF GROUNDWATER CONCENTRATIONS TO ARARs
SHEPLEY'S HILL LANDFILL – WELL GROUP 3

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION (ug/L)	ARITHMETIC AVERAGE CONCENTRATION (ug/L)	FEDERAL MCLs (ug/L)	MASS. MCLs (ug/L)	MASS. GUIDELINES (ug/L)	MASS. GROUNDWATER STANDARDS (ug/L)
UNFILTERED SAMPLES							
Aluminum	2/4	4030	1800	50–200(1)	50–200(5)	ND	ND
Arsenic	2/4	17	8.4	50	50	ND	50
Barium	4/4	28	14	2000	2000	ND	1000
Calcium	4/4	15400	1100	ND	ND	ND	ND
Chromium	2/4	7.38	5.1	100	100	ND	50
Iron	4/4	5350	2500	300 (1)	300 (5)	ND	300
Lead	2/4	7.38	3.4	15 (2)	15	ND	50
Magnesium	4/4	2850	1900	ND	ND	ND	ND
Manganese	4/4	1590	680	200/50(3/1)	50 (5)	ND	50
Potassium	4/4	2080	1900	ND	ND	ND	ND
Sodium	4/4	17300	7600	20000 (4)	ND	28000	20000
FILTERED SAMPLES							
Barium	1/1	8.71	NA	2000	2000	ND	1000
Calcium	1/1	11000	NA	ND	ND	ND	ND
Magnesium	1/1	1840	NA	ND	ND	ND	ND
Manganese	1/1	114	NA	200/50(3/1)	50 (5)	ND	50
Potassium	1/1	829	NA	ND	ND	ND	ND
Sodium	1/1	16400	NA	20000 (4)	ND	28000	20000

Notes:

Shaded line denotes either average or maximum (or both) concentration(s) of analyte exceeds at least one of the ARARs

NA = Not applicable   ND = No value available

(1) Secondary maximum contaminant level (SMCL)
(2) Treatment technique
(3) Maximum contaminant level goal (MCLG)
(4) USEPA drinking water equivalency level (DWEL) – A lifetime exposure concentration protective of adverse, noncancer health effects that assumes all exposure is from a drinking water source
(5) Massachusetts SMCL

References:

USEPA, 1993. "Drinking Water Regulations and Health Advisories." Office of Water, Washington, D.C.; May, 1993.

MADEP, 1993. "Drinking Water Standards & Guidelines for Chemicals in Massachusetts Drinking Waters." Office of Research and Standards; Boston, MA; Spring, 1993.

MADEP, 1989. "Guideance for Disposal Site Risk Characterization and Related Phase II Activities – In Support of the Massachusetts Contingency Plan." Appendix C. Office of Research and Standards; Boston, MA; July, 1991 update.

TABLE 6-33
COMPARISON OF GROUNDWATER CONCENTRATIONS TO ARARs
SHEPLEY'S HILL LANDFILL – WELL GROUP 4

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION (ug/L)	ARITHMETIC AVERAGE CONCENTRATION (ug/L)	FEDERAL MCLs (ug/L)	MASS. MCLs (ug/L)	MASS. GUIDELINES (ug/L)	MASS. GROUNDWATER STANDARDS (ug/L)
UNFILTERED SAMPLES							
Volatile Organics							
Trichlorofluoromethane	1/1	2.1	NA	ND	ND	ND	ND
Inorganics							
Aluminum	1/1	1330	NA	50–200(1)	50–200 (5)	ND	ND
Arsenic	1/1	24	NA	50	50	ND	50
Barium	1/1	39.4	NA	2000	2000	ND	1000
Calcium	1/1	15600	NA	ND	ND	ND	ND
Iron	1/1	1840	NA	300 (1)	300 (5)	ND	300
Lead	1/1	3.69	NA	15 (2)	15	ND	50
Magnesium	1/1	1900	NA	ND	ND	ND	ND
Manganese	1/1	1430	NA	200/50(3/1)	50 (5)	ND	50
Potassium	1/1	3260	NA	ND	ND	ND	ND
Sodium	1/1	7370	NA	20000 (4)	ND	28000	20000
Zinc	1/1	35.8	NA	11000/5000(4/1)	5000 (5)	ND	5000
FILTERED SAMPLES							
Barium	1/1	26.2	NA	2000	2000	ND	1000
Calcium	1/1	16900	NA	ND	ND	ND	ND
Chromium	1/1	6.95	NA	100	100	ND	50
Iron	1/1	42.5	NA	300 (1)	300 (5)	ND	300
Lead	1/1	1.63	NA	15 (2)	15	ND	50
Magnesium	1/1	1860	NA	ND	ND	ND	ND
Manganese	1/1	1850	NA	200/50(3/1)	50 (5)	ND	50
Potassium	1/1	1870	NA	ND	ND	ND	ND
Sodium	1/1	7630	NA	20000 (4)	ND	28000	20000
Zinc	1/1	28.8	NA	11000/5000(4/1)	5000 (5)	ND	5000

Notes:

Shaded line denotes either average or maximum (or both) concentration(s) of analyte exceeds at least one of the ARARs

NA = Not applicable   ND = No value available

(1) Secondary maximum contaminant level (SMCL)
(2) Treatment technique
(3) Maximum contaminant level goal (MCLG)
(4) USEPA drinking water equivalency level (DWEL) – A lifetime exposure concentration protective of adverse, noncancer health effects that assumes all exposure is from a drinking water source
(5) Massachusetts SMCL

References:

USEPA, 1993. "Drinking Water Regulations and Health Advisories." Office of Water, Washington, D.C.; May, 1993.

MADEP, 1993. "Drinking Water Standards & Guidelines for Chemicals in Massachusetts Drinking Waters." Office of Research and Standards; Boston, MA; Spring, 1993.

MADEP, 1989. "Guideance for Disposal Site Risk Characterization and Related Phase II Activities – In Support of the Massachusetts Contingency Plan." Appendix C. Office of Research and Standards; Boston, MA; July, 1991 update.

TABLE 6-34
SUMMARY OF RI HUMAN HEALTH RISK ASSESSMENT
COLD SPRING BROOK LANDFILL[1]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

POTENTIAL EXPOSURE PATHWAY		ESTIMATED EXCESS CANCER RISK			HAZARD INDICES			PRIMARY CONTRIBUTORS TO RISK[2]
		ADULT	ADOLESCENT	CHILD	ADULT	ADOLESCENT	CHILD	
Current Land Use								
Fish Ingestion	Average:	1.8E - 5	--	1.3E - 5	0.07	--	0.3	Arsenic (63%), DDD (28%)
	RME:	4.9E - 5	--	3.5E - 5	0.2	--	0.9	DDE (9%)
Sediment Contact	Average:	--	5.9E - 7	--	--	(0.005)	--	Arsenic (53%), PAHs (47%)
	RME:	--	2.5E - 6	--	--	(0.02)	--	
Assumed Future Residential Site Use								
Residential Groundwater Use	Average:	1.4E - 3	--	2.5E - 4	6.9	--	7.6	Arsenic (99%), Beryllium (1%)
	RME:	5.6E - 3	--	1.0E - 3	27	--	30	Manganese (2)
Soil Contact	Average:	1.4E - 5	--	1.9E - 5	0.0006	--	0.004	PAHs (>99%)
	RME:	2.8E - 5	--	4.1E - 5	0.001	--	0.007	
Fish Ingestion	Average:	1.8E - 4	--	1.3E - 4	0.7	--	2.9	Arsenic (63%), DDD (28%)
	RME:	4.9E - 4	--	3.5E - 4	2.1	--	9.3	DDE (9%), Zinc (3.4)
Sediment Contact	Average:	--	1.2E - 5	--	--	(0.11)	--	Arsenic (57%), PAHs (43%)
	RME:	--	4.9E - 5	--	--	(0.37)	--	
Total Risk	Average:	1.6E - 3	1.2E - 5	4.0E - 4	7.6	(0.11)	10	
	RME:	6.1E - 3	4.9E - 5	1.4E - 3	29	(0.37)	39	

Notes:
[1] Excerpted from Tables 8-61 through 8-64 of the RI Risk Assessment, April 1993.
[2] In parentheses is the percentage that a carcinogen contributes to the total cancer risk or, for a noncarcinogen, the hazard index.

TABLE 6-35

COMPARISON OF AVERAGE AND MAXIMUM SURFACE WATER CONCENTRATIONS
TO DRINKING WATER STANDARDS
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	AVERAGE CONCENTRATION (ug/L)	MAXIMUM CONCENTRATION (ug/L)	DRINKING WATER STANDARDS (ug/L)	
Inorganics:				
Arsenic	7.7	17.7	50	(1)
Barium	10.7	13.4	2000	(1)
Chromium	2.7	4.76	100	(1)
Copper	4.4	6.75	1300	(2)
Iron	1560	3200	NA	(3)
Manganese	151	400	200	(2)
Silver	0.2	0.708	200	(4)
Zinc	21.8	86.3	11,000	(4)

Notes:

(1) Federal Maximum Contaminant Level (MCL)

(2) Federal Maximum Contaminant Level Goal (MCLG)

(3) NA = No health-based standard is available

(4) USEPA Health Advisory based on lifetime exposure

TABLE 6-36
SUMMARY OF GROUNDWATER SAMPLING RESULTS[1]
COLD SPRING BROOK LANDFILL - DOWNGRADIENT WELLS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION (ug/L)	ARITHMETIC MEAN (ug/L)	COPC (Y/N)
UNFILTERED SAMPLES [2]				
bis(2-Ethylhexyl)phthalate	2 / 4	14	4	Y
Aluminum	3 / 4	20500	3948.3	Y
Arsenic	2 / 4	40	14	Y
Barium	4 / 4	112	41.1	Y
Calcium	4 / 4	164000	69283.7	Y
Chromium	1 / 4	30.8	8	Y
Copper	2 / 4	31	11.4	Y
Iron	4 / 4	25400	9593.6	Y
Lead	3 / 4	13.4	4.1	Y
Magnesium	4 / 4	28900	12293.8	Y
Manganese	4 / 4	5700	2504.3	Y
Nickel	1 / 4	49	21.1	Y
Potassium	4 / 4	8540	5554.4	Y
Sodium	4 / 4	42900	18081.3	Y
Vanadium	1 / 4	26.3	8.1	Y
Zinc	1 / 4	60.1	19.5	Y
FILTERED SAMPLES [3]				
Arsenic	1 / 3	19.8	4.9	Y
Barium	3 / 3	36.8 BB	NA	N
Calcium	3 / 3	148000	64473.3	Y
Iron	2 / 3	14600	3156.8	Y
Magnesium	3 / 3	25000	11471.7	Y
Manganese	3 / 3	6120	2983	Y
Potassium	3 / 3	17000	5930.8	Y
Sodium	3 / 3	18600	13195	Y
Vanadium	1 / 3	11.9	7.6	Y

Notes:
ug/L = Micrograms per liter
BB = Less than background concentration
NA = Not applicable
[1] Includes Round 1 (March 1993) and Round 2 (June 1993) data; wells CSM-93-01A, CSM-92-02A, and CSM-93-02B were sampled in both rounds. Well CSB-2 was sampled in Round 1 only.
[2] Unfiltered samples from monitoring wells CSB-2, CSM-93-01A, CSM-93-02A, CSM-93-02B
[3] Filtered samples from monitoring wells CSB-2, CSM-93-01A, CSM-93-02A

TABLE 6-37

SUMMARY STATISTICS FOR FISH TISSUE ANALYTE CONCENTRATIONS[1]

PUMPKINSEEDS (WHOLE FISH)

COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT

FEASIBILITY STUDY FOR GROUP 1A SITES

FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MINIMUM CONCENTRATION	MAXIMUM CONCENTRATION	AVERAGE CONCENTRATION
Pesticides/PCBs (ug/kg)				
DDE	3/3	22	170	83.33
DDD	3/3	19	230	115.33
Inorganics (mg/kg)				
Arsenic	1/3	0.27	0.27	0.15
Barium	3/3	0.24	0.64	'0.473
Calcium	3/3	8510	15500	13136
Chromium	3/3	0.23	0.33	0.297
Cobalt	2/3	0.11	0.2	0.12
Copper	3/3	0.37	0.41	0.39
Iron	3/3	24.6	41.5	32.93
Magnesium	3/3	325	464	416.67
Manganese	3/3	7.6	12	10
Mercury	3/3	0.08	0.24	0.157
Selenium	2/3	0.24	0.45	0.247
Sodium	3/3	1060	1280	1173.33
Zinc	3/3	17.2	24.1	21

Notes:

[1] Table includes detected analytes only

TABLE 6-38
SUMMARY STATISTICS FOR FISH TISSUE ANALYTE CONCENTRATIONS[1]
BULLHEADS AND PICKERELS (FILLETS)
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A Sites
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION	MINIMUM CONCENTRATION	MAXIMUM CONCENTRATION	AVERAGE CONCENTRATION
Pesticides (ug/kg)				
DDE	2/6	12	21	11.942
DDD	2/6	33	50	19.275
Inorganics (mg/kg)				
Arsenic	5/6	0.14	0.32	0.2
Calcium	6/6	93.3	505	217.383
Copper	6/6	0.18	0.35	0.295
Iron	6/6	1.83	9.1	6.105
Magnesium	6/6	229	329	269.167
Manganese	2/6	0.58	1	0.367
Mercury	6/6	0.15	0.46	0.305
Selenium	6/6	0.14	0.24	0.183
Sodium	6/6	343	455	385
Zinc	6/6	3.6	6.5	5.45

Note:
[1] Table includes detected analytes only.

TABLE 6-39
SUMMARY STATISTICS FOR SHALLOW SEDIMENT[1]
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CONCENTRATION AVERAGE (ug/g)	CONCENTRATION MAXIMUM (ug/g)	FREQUENCY OF DETECTION	COPC (Y/N)
Organics				
acetone	0.02	0.17	8/9	N
methylene chloride	0.01	0.061	9/9	N
2-butanone	0.003	0.025	1/9	N
acenapthene	0.18	0.87	1/25	Y
acenapthylene	0.26	3	1/25	Y
anthracene	0.27	3	1/25	Y
benzo(a)anthracene	0.51	4	2/25	Y
benzo(a)pyrene	1.1	6	2/25	Y
benzo(b)fluoranthene	0.64	5	2/25	Y
benzo(g,h,i)perylene	0.48	1	1/25	Y
benzo(k)fluoranthene	0.9	10	2/25	Y
bis(2-ethylhexyl)phthalate	1.4	2	1/25	Y
chrysene	0.63	8	2/25	Y
dibenzofuran	0.15	0.61	2/25	Y
fluoranthene	1.6	10	11/25	Y
fluorene	0.16	0.2	1/25	Y
indeno(1,2,3-cd)pyrene	0.56	2	1/25	Y
naphthalene	0.14	0.25	1/25	Y
phenanthrene	0.77	6	3/25	Y
pyrene	2.2	20	5/25	Y
DDD	0.5	6.2	16/25	Y
DDE	0.09	0.72	14/25	Y
DDT	0.64	15	6/25	Y
Inorganics				
aluminum	6,108	17,000	25/25	Y
arsenic	78	390	25/25	Y
barium	36.8	115	24/25	Y
beryllium	0.19	0.41	2/25	Y
calcium	8,582	41,600	20/25	Y
cobalt	3.38	19.6	8/25	Y
chromium	15.1	64.8	15/25	Y
copper	8.5	42.9	16/25	Y
iron	15,232	45,000	25/25	Y
potassium	758	3,580	22/25	Y
lead	69.5	570	25/25	Y
magnesium	2,246	7,160	25/25	Y
manganese	634	3,000	25/25	Y
mercury	0.077	0.72	7/25	Y
nickel	10.8	54.3	16/25	Y
selenium	1.96	5.77	5/25	Y
silver	0.65	6.35	4/25	Y
sodium	452	1,860	20/25	Y
vanadium	12.1	48.6	18/25	Y
zinc	82.3	690	17/25	Y

Notes:
[1] Based on sediment samples SE-CSB-01 through SE-CSB-09 (April 1993 RI) and CSD-92-01 through CSD-92-16, at depths of less than one foot.

Table 6-40
CHEMICALS OF POTENTIAL CONCERN IN HUMAN HEALTH RISK ASSESSMENT
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHEMICAL OF POTENTIAL CONCERN	FISH TISSUE	SEDIMENT	GROUNDWATER
Inorganics			
Aluminum		X	X
Arsenic	X	X	X
Barium	X	X	X
Beryllium		X	
Calcium	X	X	X
Chromium	X	X	X
Cobalt	X	X	
Copper	X	X	X
Iron	X	X	X
Lead		X	X
Magnesium	X	X	X
Manganese	X	X	X
Mercury	X	X	
Nickel		X	X
Potassium		X	X
Selenium	X	X	X
Silver		X	
Sodium	X	X	X
Vanadium		X	X
Zinc	X	X	X
SVOCs			
Acenaphthene		X	
Acenaphthylene		X	
Anthracene		X	
Benzo(a)anthracene		X	
Benzo(a)pyrene		X	
Benzo(b)fluoranthene		X	
Benzo(g,h,i)perylene		X	
Benzo(k)fluoranthene		X	
Bis(2-ethylhexyl)phthalate		X	X
Chrysene		X	
Dibenzofuran		X	
Fluoranthene		X	
Fluorene		X	
Indeno(1,2,3-c,d)pyrene		X	
Naphthalene		X	
Phenanthrene		X	
Pyrene		X	
Pesticides/PCBs			
DDD	X	X	
DDE	X	X	
DDT		X	

TABLE 6-41
EXPOSURE PARAMETER VALUES
PATHWAY: GROUNDWATER INGESTION AND CONTACT DURING SHOWERING
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

PARAMETER	RECEPTOR	CASE	PARAMETER VALUE	SOURCE	COMMENTS
Water Concentration	Adult/Child	Average	Average concentration	–	–
	Adult/Child	RME	Maximum concentration	–	–
Ingestion Rate	Adult	Average/RME	2 liters/day	Standard Default[1]	90th percentile
	Child	Average/RME	0.5 liters/day	Exposure Factors (Table 2-4)[2]	Mean, ages 5-9
Surface Area (SA) Exposed	Adult	Average/RME	19,400 cm^2	Exposure Factors (Table 4-1)	Mean SA, males
	Child	Average/RME	4545.3 cm^2-yr/kg	See Appendix V	Represents normalized surface area and total body
Body Weight	Adult	Average/RME	70 kg	Standard Default	Average, adult
	Child	Average/RME	16 kg	Exposure Factors (Table 5-3)	Average, ages 3-6
Shower/Bath Exposure Time	Adult	Average/RME	0.2 hours/day	RAGs[3] (Exhibit 6-16)	90th percentile
	Child	Average/RME	0.2 hours/day	RAGs[3] (Exhibit 6-16)	90th percentile
Exposure Frequency	Adult	Average/RME	350 days/year	Standard Default	–
	Child	Average/RME	350 days/year	Standard Default	–
Exposure Duration	Adult	Average/RME	30 years	RAGs (Exhibit 6-11)	90th percentile; national upper bound time at one residence
	Child	Average/RME	5 years	–	Length of time in age range
Averaging Time (cancer)	Adult	Average/RME	70 years	RAGs (Exhibit 6-11)	Lifetime by convention
	Child	Average/RME	70 years	RAGs (Exhibit 6-11)	Lifetime by convention
Averaging Time (noncancer)	Adult	Average/RME	30 years	RAGs (Exhibit 6-11)	AT = ED
	Child	Average/RME	5 years	RAGs (Exhibit 6-11)	AT = ED

Notes:
RME = Reasonable Maximum Exposure
[1]USEPA Standard Default Exposure Factors (USEPA, 1991b)
[2]USEPA Exposure Factors Handbook (USEPA, 1989b)
[3]USEPA Risk Assessment Guidance for Superfund (RAGs) (USEPA,1989f)

TABLE 6-42
EXPOSURE PARAMETER VALUES
PATHWAY: INGESTION OF FISH
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

PARAMETER	RECEPTOR	CASE	PARAMETER VALUE	SOURCE	COMMENTS
Fish Concentration	Adult/Child	Average	Average Concentration	-	-
	Adult/Child	RME	Maximum Concentration	-	-
Fish Ingestion Rate	Adult	Average/RME	54 grams/day	Standard Default[1]	Average, adult
	Child	Average/RME	16.5 grams/day	Exposure Factors (Table 2-15)[2]	95th percentile, ages 0-9
Fraction Ingested from Source	Adult	Average/RME	0.05	Assumption	-
	Child	Average/RME	0.05	Assumption	-
Body Weight	Adult	Average/RME	70 kg	Standard Default	Average, adult
	Child	Average/RME	16 kg	Exposure Factors (Table 5-3)	Average, ages 3-6
Exposure Frequency	Adult	Average/RME	350 days/year	Standard Default	-
	Child	Average/RME	350 days/year	Standard Default	-
Exposure Duration	Adult	Average/RME	30 years	Standard Default (Table 1)	90th percentile: national upper bound time at one residence
	Child	Average/RME	5 years	-	Length of time in age range
Averaging Time (cancer)	Adult	Average/RME	70 years	RAGS[3] (Exhibit 6-17)	Lifetime by convention
	Child	Average/RME	70 years	RAGS (Exhibit 6-17)	
Averaging Time (noncancer)	Adult	Average/RME	30 years	RAGS (Exhibit 6-17)	AT = ED
	Child	Average/RME	5 years	RAGS (Exhibit 6-17)	AT = ED

RME = Reasonable Maximum Exposure
[1] USEPA Standard Default Exposure Factors (USEPA, 1991b)
[2] USEPA Exposure Factors Handbook (USEPA, 1989b)
[3] USEPA Risk Assessment Guidance for Superfund (RAGs) (USEPA.1989f)

TABLE 6-43
EXPOSURE PARAMETER VALUES
PATHWAY: SEDIMENT INGESTION AND CONTACT
COLD SPRING BROOK LANDFILL

**REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA**

PARAMETER	RECEPTOR	CASE	PARAMETER VALUE	SOURCE	COMMENTS
Sediment Concentration	Adolescent	Average RME	Average Concentration Maximum Concentration	–	–
Ingestion Rate	Adolescent	Average/RME	100 mg/day	Standard Default[1]	Upper-bound value for individual > 6 years of age
Fraction Ingested	Adolescent	Average/RME	100%	Assumption	–
Soil Adherence Factor	Adolescent	Average/RME	0.5 mg/cm^2	Dermal Exposure (Table 8-6)[2]	Between central and upper-bound value in range
Surface Area Exposed	Adolescent	Average/RME	848.6 cm^2-yr/kg	See Appendix V	Represents normalized surface area and 25% of total body
Body Weight	Adolescent	Average/RME	42 kg	Exposure Factors (Table 5-3)[3]	Average, ages 6-16
Exposure Frequency	Adolescent (current use) Adolescent (future use)	Average/RME Average/RME	5 days/year 100 days/year	Assumption Assumption	1 day/month, May through September More frequent exposure based on future residential land use
Exposure Duration	Adolescent	Average/RME	10 years	–	Length of time in age range
Averaging Time (cancer)	Adolescent	Average/RME	70 years	RAGS (Exhibit 6-15)[4]	Lifetime by convention
Averaging Time (noncancer)	Adolescent	Average/RME	10 years	RAGS (Exhibit 6-15)	AT = ED

Notes:
RME = Reasonable Maximum Exposure
[1]USEPA Standard Default Exposure Factors (USEPA, 1991b)
[2]USEPA Dermal Exposure Assessment:Principles and Applications (USEPA, 1992d)
[3]USEPA Exposure Factors Handbook (USEPA, 1989b)
[4]USEPA Risk Assessment Guidance for Superfund (RAGs) (USEPA,1989f)

TABLE 6-44
ORAL DOSE/RESPONSE INFORMATION FOR CARCINOGENIC EFFECTS
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	WEIGHT OF EVIDENCE	SLOPE FACTOR $[(mg/kg/day)^{-1}]$	SOURCE	TEST SPECIES	EXPOSURE ROUTE	TUMOR TYPE	STUDY SOURCE
SVOCs							
Benzo(a)anthracene	B2	7.30E+00	(1)				
Benzo(a)pyrene	B2	7.30E+00	IRIS	Mouse	Oral-diet	Forestomach	IRIS
Benzo(b)fluoranthene	B2	7.30E+00	(1)				
Benzo(k)fluoranthene	B2	7.30E+00	(1)				
Bis(2-ethylhexyl)phthalate	B2	1.40E-02	IRIS	Rat	Oral-diet	Liver	IRIS
Chrysene	B2	7.30E+00	(1)				
Indeno(1,2,3-cd)pyrene	B2	7.30E+00	(1)				
Pesticides/PCBs							
DDD	B2	2.40E-01	IRIS	Mouse	Oral-diet	Liver	IRIS
DDE	B2	3.40E-01	IRIS	Mouse/hamster	Oral-diet	Liver	IRIS
DDT	B2	3.40E-01	IRIS	Mouse/rat	Oral-diet	Liver	IRIS
Inorganics							
Arsenic	A	1.75E+00	IRIS (2)	Human	Oral-drinking water	Skin	IRIS
Beryllium	B2	4.30E+00	IRIS	Rat	Oral-drinking water	Total	IRIS
Lead	B2	NE					

Notes:
NE = Not Evaluated
Integrated Risk Information System (IRIS) on-line database search, current as of December 1993.
Health Effects Assessment Summary Tables (HEAST), current as of July 1993.
(1) The ingestion slope factor for benzo(a)pyrene was used as a surrogate for all PAHs classified as A or B carcinogens and for which a chemical-specific slope factor was not available.
(2) The ingestion slope factor for arsenic has been calculated from the drinking water unit risk of 5.00E-05 per(ug/L).

Weight of Evidence (route-specific):
A = Human carcinogen
B = Probable human carcinogen (B1 = limited human evidence; B2 = sufficient human evidence)

TABLE 6-45
ORAL DOSE/RESPONSE DATA FOR NONCARCINOGENIC EFFECTS
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CHRONIC ORAL RfD (mg/kg-day)	SOURCE	SUBCHRONIC ORAL RfD (1) (mg/kg-day)	SOURCE	STUDY TYPE	CONFIDENCE LEVEL	CRITICAL EFFECT	TEST ANIMAL	UNCERTAINTY FACTOR	STUDY SOURCE
SVOCs										
Acenaphthene	6.00E-02	IRIS	6.00E-01	HEAST	Oral-gavage	Low	Hepatotoxicity	Mouse	3000 H,A,S,D	IRIS
Acenaphthylene	4.00E-02	(3)	ND							
Anthracene	3.00E-01	IRIS	3.00E+00	HEAST	Gavage	Low	No observed effects	Mouse	3000 H,A,S	IRIS
Benzo(a)anthracene	4.00E-02	(3)	ND							
Benzo(a)pyrene	4.00E-02	(3)								
Benzo(b)fluoranthene	4.00E-02	(3)								
Benzo(k)fluoranthene	4.00E-02	(3)								
Benzo(g,h,i)perylene	4.00E-02	(3)								
Bis(2-ethylhexyl)phthalate	2.00E-02	IRIS	2.00E-02	IRIS	Oral-diet	Medium	Increased liver weight	Guinea Pig	1000 H,A,S	IRIS
Chrysene	4.00E-02	(3)	ND							
Dibenzofuran	ND		ND							
Fluoranthene	4.00E-02	IRIS	4.00E-01	HEAST	Oral-gavage	Low	Increased liver weight, clinical effects	Mouse	3000 H,A,S,D	IRIS
Fluorene	4.00E-02	IRIS	4.00E-01	HEAST	Oral-gavage	Low	Hematological changes	Mouse	3000 H,A,S,D	IRIS
Indeno(1,2,3-cd)pyrene	4.00E-02	(3)	ND							
Naphthalene	4.00E-02	(7)	ND	(7)	Gavage		Decreased body weight gain	Rat	1000	HEAST
Phenanthrene	4.00E-02	(3)	ND							
Pyrene	3.00E-02	IRIS	3.00E-01	HEAST	Oral-gavage	Low	Renal tubular pathology	Mouse	3000 H,A,S,D	IRIS
Pesticides/PCBs										
DDD	5.00E-04	(4)	5.00E-04	(4)						
DDE	5.00E-04	(4)	5.00E-04	(4)						
DDT	5.00E-04	IRIS	5.00E-04	HEAST	Oral-diet	Medium	Liver lesions	Rat	100 H,A	IRIS
Inorganics										
Aluminum	ND		ND							
Arsenic	3.00E-04	IRIS	3.00E-04	HEAST	Oral-drinking water	Medium	Hyperpigmentation, keratosis	Human	3 D	IRIS
Barium	7.00E-02	IRIS	7.00E-02	HEAST	Oral-drinking water	Medium	Elevated blood pressure	Human	3 H	IRIS
Beryllium	5.00E-03	IRIS	5.00E-03	HEAST	Oral-drinking water	Low	No effects observed	Rat	100 H,A	IRIS
Calcium	ND		ND							
Chromium III	1.00E+00	IRIS	1.00E+00	HEAST	Oral-diet	Low	No effects observed	Rat	100 H,A	IRIS
Chromium VI	5.00E-03	IRIS	2.00E-02	HEAST	Oral-drinking water	Low	No effects observed	Rat	500 H,A,S	IRIS
Cobalt	ND		ND							
Copper	ND		ND							
Iron	ND		ND							
Lead	ND		ND							
Magnesium	ND		ND							

TABLE 6-45
ORAL DOSE/RESPONSE DATA FOR NONCARCINOGENIC EFFECTS
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CHRONIC ORAL RfD (mg/kg-day)	SOURCE	SUBCHRONIC ORAL RfD (1) (mg/kg-day)	SOURCE	STUDY TYPE	CONFIDENCE LEVEL	CRITICAL EFFECT	TEST ANIMAL	UNCERTAINTY FACTOR	STUDY SOURCE
Manganese (food)	1.40E-01	IRIS	1.40E-01	HEAST	Oral-diet	NA	CNS effects	Human	1	IRIS
Manganese (water)	5.00E-03	IRIS	5.00E-03	HEAST	Oral-drinking water	NA	No effects observed	Human	1	IRIS
Mercury	3.00E-04	HEAST (2,5)	3.00E-04	HEAST	Oral-gavage	Low	Kidney effects	Rat	1000 H,A,D	HEAST
Nickel	2.00E-02	IRIS (6)	2.00E-02	HEAST	Oral-diet	Medium	Decreased body, organ weights	Rat	300 H,A,D	IRIS
Potassium	ND		ND							
Selenium	5.00E-03	IRIS	5.00E-03	HEAST	Oral-diet	High	Selenosis	Human	3 H	IRIS
Silver	5.00E-03	IRIS	5.00E-03	HEAST	Injection-i.v.	Low	Argyria	Human	3 H	IRIS
Sodium	ND		ND							
Vanadium	7.00E-03	HEAST (2)	7.00E-03	HEAST	Oral-drinking water	Low	No effects observed	Rat	100 H,A	HEAST
Zinc	3.00E-01	IRIS	3.00E-01	HEAST	Oral-diet supplemen	Medium	Decrease in ESOD activity	Human	3 S	IRIS

Notes:
ND = No Data
NA = Not Applicable
Integrated Risk Information System (IRIS) on-line database search, current as of December 1993.
Health Effects Assessment Summary Tables (HEAST), current as of July 1993.
(1) The chronic RfD will be used as a surrogate for compounds without subchronic RfDs.
(2) This value is currently listed in HEAST, but has been withdrawn from IRIS and is under review.
(3) The RfD for naphthalene is used as a surrogate for PAHs without assigned RfDs.
(4) The RfD for 4,4-DDT is used as a surrogate.
(5) This mercury value is specific for inorganic mercury.
(6) The ingestion RfD values for nickel are based on nickel, soluble salts.
(7) The values for naphthalene have been withdrawn from IRIS and HEAST and are currently under review.

Uncertainty factors:
H = Variation in human sensitivity
A = Animal to human extrapolation
S = Extrapolation from subchronic to chronic NOAEL
L = Extrapolation from LOAEL to NOAEL
D = Inadequate data
M = Modifying factor

TABLE 6-46
DERMAL DOSE/RESPONSE DATA
FOR CARCINOGENIC EFFECTS
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	WEIGHT OF EVIDENCE	ORAL SLOPE FACTOR [a] $[(mg/kg/day)^{-1}]$	ABSORPTION EFFICIENCY	REFERENCE	ADJUSTED SLOPE FACTOR $[(mg/kg/day)^{-1}]$
SVOCs					
Benzo(a)anthracene	B2	7.30E+00	91%	[b]	8.02E+00
Benzo(a)pyrene	B2	7.30E+00	91%	Hecht et al., 1979	8.02E+00
Benzo(b)fluoranthene	B2	7.30E+00	91%	[b]	8.02E+00
Benzo(k)fluoranthene	B2	7.30E+00	91%	[b]	8.02E+00
bis(2-Ethylhexyl)phthalate	B2	1.40E-02	100%	Chadwick et al., 1982	1.40E-02
Chrysene	B2	7.30E+00	91%	[b]	8.02E+00
Indeno(1,2,3-c,d)pyrene	B2	7.30E+00	91%	[b]	8.02E+00
Pesticides/PCBs					
DDD	B2	2.40E-01	20%	[c]	1.20E+00
DDE	B2	3.40E-01	20%	[c]	1.70E+00
DDT	B2	3.40E-01	20%	Siebert, 1976	1.70E+00
Inorganics					
Arsenic	A	1.75E+00	98%	Vahter, 1983	1.79E+00
Beryllium	B2	4.30E+00	1%	Owen, 1990	4.30E+02
Lead	B2	ND	NA		ND

Notes:
ND = Not Determined
NA = Not Applicable
[a] For documentation concerning oral slope factors, refer to Table 6-45.
[b] The oral absorption of this compound is assumed to be identical to that of benzo(a)pyrene (Hecht et al., 1979), based on structural analogy.
[c] The oral absorption of this compound is assumed to be identical to that of DDT (Siebert, 1976), based on structural analogy.

Weight of Evidence (route-specific):
A = Human carcinogen
B = Probable human carcinogen (B1 = limited human evidence; B2 = sufficient human evidence)

TABLE 6-47
DERMAL DOSE/RESPONSE DATA
FOR NONCARCINOGENIC EFFECTS
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CHRONIC ORAL RfD [a] (mg/kg-day)	SUBCHRONIC ORAL RfD [a] (mg/kg-day)	ABSORPTION EFFICIENCY	REFERENCE	ADJUSTED CHRONIC RfD (mg/kg-day)	ADJUSTED SUBCHRONIC RfD (mg/kg-day)
SVOCs						
Acenaphthene	6.00E-02	6.00E-01	91%	[d]	5.46E-02	5.46E-01
Acenaphthylene	4.00E-02	4.00E-02	100%	[c]	4.00E-02	4.00E-02
Anthracene	3.00E-01	3.00E+00	91%	[d]	2.73E-01	2.73E+00
Benzo(a)anthracene	4.00E-02	4.00E-02	100%	[c]	4.00E-02	4.00E-02
Benzo(a)pyrene	4.00E-02	4.00E-02	100%	[c]	4.00E-02	4.00E-02
Benzo(b)fluoranthene	4.00E-02	4.00E-02	100%	[c]	4.00E-02	4.00E-02
Benzo(g,h,i)perylene	4.00E-02	4.00E-02	100%	[c]	4.00E-02	4.00E-02
Benzo(k)fluoranthene	4.00E-02	4.00E-02	100%	[c]	4.00E-02	4.00E-02
bis(2-Ethylhexyl)phthalate	2.00E-02	2.00E-02	100%	Chadwick et al., 1982	2.00E-02	2.00E-02
Chrysene	4.00E-02	4.00E-02	100%	[c]	4.00E-02	4.00E-02
Dibenzofuran	ND	ND	NA		ND	ND
Fluoranthene	4.00E-02	4.00E-01	91%	[d]	3.64E-02	3.64E-01
Fluorene	4.00E-02	4.00E-01	91%	[d]	4.00E-02	4.00E-01
Indeno(1,2,3-c,d)pyrene	4.00E-02	4.00E-02	100%	[c]	4.00E-02	4.00E-02
Naphthalene	4.00E-02	4.00E-02	100%	[c]	4.00E-02	4.00E-02
Phenanthrene	4.00E-02	4.00E-02	100%	[c]	4.00E-02	4.00E-02
Pyrene	3.00E-02	3.00E-01	91%	[d]	2.73E-02	2.73E-01
Pesticides/PCBs						
DDD	5.00E-04	5.00E-04	20%	[e]	1.00E-04	1.00E-04
DDE	5.00E-04	5.00E-04	20%	[e]	1.00E-04	1.00E-04
DDT	5.00E-04	5.00E-04	20%	Siebert, 1976	1.00E-04	1.00E-04
Inorganics						
Aluminum	ND	ND	NA		ND	ND
Arsenic	3.00E-04	3.00E-04	98%	Vahter, 1983	2.94E-04	2.94E-04
Barium	7.00E-02	7.00E-02	7%	ATSDR, 1991c	4.90E-03	4.90E-03
Beryllium	5.00E-03	5.00E-03	1%	Owen, 1990	5.00E-05	5.00E-05
Calcium	ND	ND	NA		ND	ND

TABLE 6-47
DERMAL DOSE/RESPONSE DATA
FOR NONCARCINOGENIC EFFECTS
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CHRONIC ORAL RfD [a] (mg/kg-day)	SUBCHRONIC ORAL RfD [a] (mg/kg-day)	ABSORPTION EFFICIENCY	REFERENCE	ADJUSTED CHRONIC RfD (mg/kg-day)	ADJUSTED SUBCHRONIC RfD (mg/kg-day)
Chromium						
Trivalent	1.00E+00	1.00E+00	10%	ATSDR, 1989a	1.00E-01	1.00E-01
Hexavalent	5.00E-03	2.00E-02	11%	Ogawa, 1976	5.50E-04	2.20E-03
Cobalt	ND	ND	NA		ND	ND
Copper	ND	ND	NA		ND	ND
Iron	ND	ND	NA		ND	ND
Lead	ND	ND	NA		ND	ND
Magnesium	ND	ND	NA		ND	ND
Manganese						
Dietary exposure	1.40E-01	1.40E-01	4%	ATSDR, 1991b	5.60E-03	5.60E-03
Drinking water exposure	5.00E-03	5.00E-03	4%	ATSDR, 1991b	2.00E-04	2.00E-04
Mercury	3.00E-04	3.00E-04	20%	Nielsen, 1992	6.00E-05	6.00E-05
Nickel	2.00E-02	2.00E-02	5%	Christenson & Lagesson, 1981	1.00E-03	1.00E-03
Potassium	ND	ND	NA		ND	ND
Selenium	5.00E-03	5.00E-03	60%	Owen, 1990	3.00E-03	3.00E-03
Silver	5.00E-03	5.00E-03	21%	MacIntyre et al., 1978	1.05E-03	1.05E-03
Sodium	ND	ND	NA		ND	ND
Vanadium	7.00E-03	7.00E-03	3%	ATSDR, 1991d	2.10E-04	2.10E-04
Zinc	3.00E-01	3.00E-01	34%	Sandstrom et al., 1987	1.02E-01	1.02E-01

Notes:
ND = No Data Available
NA = Not Applicable
[a] For documentation concerning chronic and subchronic oral RfDs, refer to Table 6-46.
[b] VOCs lacking specific absorption information are assumed to have an absorption efficiency of 100%, based on analogy with other VOCs.
[c] The oral absorption of PAHs lacking chemical-specific RfDs is assumed to be identical to that of naphthalene (Chang, 1943).
[d] The oral absorption of PAHs with chemical-specific RfDs is assumed to be identically to that of benzo(a)pyrene (Hecht et al., 1979), based on structural analogy.
[e] The oral absorption of this compound is assumed to be identical to that of DDT (Siebert, 1976), based on structural analogy.

Table 6–48
DEFAULT ABSORPTION FRACTIONS
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE PATHWAY	COMPOUND	DEFAULT ABSORPTION FRACTIONS		
		DERMAL	INGESTION	INHALATION
Direct Contact with Sediment[1]	VOCs	50%	100%	NA
	SVOCs			
	PAHs	5%	100%	NA
	PCBs	5%	30%	NA
	Pesticides			
	–high sorption to soils (e.g., chlordane, DDD, DDT)	5%	30%	NA
	–low sorption to soils (e.g., lindane, acrolein)	50%	100%	NA
	Inorganics	Negligible	100% (except lead)	NA
	Lead	Negligible	30% adults	NA
			50% children (age 1–6)	NA
Ingestion of Groundwater[1]	All Compounds	NA	100%	NA
Ingestion of Fish	All Compounds	NA	100%	NA
Inhalation of VOCs in Shower	All VOCs	NA	NA	100%

Notes:

NA = Not Applicable

[1] Default USEPA Region I Absorption Fractions (USEPA, 1989c)

TABLE 6-49
SUMMARY OF CANCER RISK ESTIMATES
CURRENT LAND USE
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE SCENARIO	ADULT		ADOLESCENT		CHILD		RISK CONTRIBUTIONS[1] (BY CHEMICAL)
	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	
Ingestion of Pumpkinseeds	5E-06	9E-06	NA	NA	1E-06	2E-06	Arsenic (81%)[2]
Ingestion of Fillets (bullhead and pickerel)	6E-06	9E-06	NA	NA	1E-06	2E-06	Arsenic (97%)
Sediment Contact	NA	NA	1E-06	6E-06	NA	NA	Arsenic (59%)[3]
Surface Soil Contact[4]	2E-07	4E-07	NA	NA	3E-07	6E-07	Cancer Risk $<1x10^{-6}$
Total Risk[5]	7E-06	2E-05	NA	NA	1E-06	3E-06	

Notes:
[1] Risk contributions were calculated before rounding off risk estimates for individual chemicals and for the summary risk estimate.
[2]Two other COPCs contributed to total risk: DDE (at $9.2x10^{-7}$ or 10% of the total) and DDD (at $8.7x10^{-7}$ or 9% of the total); both risks are below the USEPA point of departure of $1x10^{-6}$.
[3]PAHs contributed the majority of the remaining risk (37%): benzo(a)anthracene ($2.7x10^{-7}$), chrysene ($5.4x10^{-7}$), benzo(a)pyrene ($4.0x10^{-7}$), benzo(b)fluoranthene ($3.4x10^{-7}$), benzo(k)fluoranthene($6.7x10^{-7}$), and indeno(1,2,3-cd)pyrene ($1.3x10^{-7}$).
[4] Risks from surface soil exposure (ingestion and dermal contact) are reported in the RI Report (April, 1993).
[5] For an adult, includes ingestion of fillets and sediment as an adolescent and soil contact. For a child, includes ingestion of fillets and soil contact.
NA= Not Applicable
EPC= Exposure Point Concentration

TABLE 6-50
SUMMARY OF NONCANCER RISK ESTIMATES
CURRENT LAND USE
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE SCENARIO	ADULT		ADOLESCENT		CHILD		RISK CONTRIBUTIONS[1,2] (BY CHEMICAL)
	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	
Ingestion of Pumpkinseeds	0.06	0.1	NA	NA	0.08	0.1	HIs[3]<1
Ingestion of Fillets (bullhead and pickerel)	0.07	0.1	NA	NA	0.09	0.1	HIs<1
Sediment Contact	NA	NA	0.01	0.06	NA	NA	HIs<1
Surface Soil Contact[4]	0.000009	0.00002	NA	NA	0.00006	0.0001	HIs<1
Total Risk[5]	0.07	0.1	0.01	0.06	0.09	0.1	

Notes:
[1]Hazard quotients for individual chemicals shown in parentheses, at average and maximum EPCs, respectively, for receptor showing greatest risk.
[2]Hazard indices for mixtures have been rounded to one significant figure while a hazard quotient for an individual chemical may have more than one significant figure.
[3]HIs= hazard indices for mixtures
[4] Risks for exposure to surface soil (ingestion and dermal contact) as reported in the RI Report (April, 1993).
[5] For an adult and child, includes fillet ingestion and soil contact. For an adolescent, includes sediment contact only.
NA= Not Applicable
EPC= Exposure Point Concentration

TABLE 6–51
SUMMARY OF CANCER RISK ESTIMATES
FUTURE LAND USE
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE SCENARIO	ADULT		ADOLESCENT		CHILD		RISK CONTRIBUTIONS[1] (BY CHEMICAL)
	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	
Ingestion of Pumpkinseeds	5E–06	9E–06	NA	NA	1E–06	2E–06	Arsenic (81%)[2]
Ingestion of Fillets (bullhead and pickerel)	6E–06	9E–06	NA	NA	1E–06	2E–06	Arsenic (97%)
Sediment Contact	NA	NA	2E–05	1E–04	NA	NA	Arsenic (58%) PAHs (36%)[3]
Surface Soil Contact[4]	1E–05	3E–05	NA	NA	2E–05	4E–05	PAHs (99%)
Residential Groundwater Use (downgradient wells)							
Unfiltered	6E–05	2E–04	NA	NA	1E–05	3E–05	Arsenic[5] (97%)
Filtered	2E–05	8E–05	NA	NA	4E–06	2E–05	Arsenic (100%)
Total Risk[6]							
Unfiltered	1E–04	3E–04	NA	NA	3E–05	7E–05	
Filtered	6E–05	2E–04	NA	NA	3E–05	6E–05	

Notes:

[1] Risk contributions were calculated before rounding off risk estimates for individual chemicals and for the summary risk estimate.

[2] Two other COPCs contributed to total risk: DDE (at $9.2x10^{-7}$ or 10% of the total) and DDD (at $8.7x10^{-7}$ or 9% of the total); both risks are below the USEPA point of departure of $1x10^{-6}$.

[3] PAHs contributed 36% to the total risk: benzo(a)anthracene ($5.4x10^{-6}$), chrysene ($1.1x10^{-5}$), benzo(a)pyrene ($8.1x10^{-6}$), benzo(b)fluoranthene ($6.7x10^{-6}$), benzo(k)fluoranthene ($1.3x10^{-5}$), and indeno(1,2,3–cd) pyrene ($2.7x10^{-6}$).

[4] Risks for surface soil exposure (ingestion and dermal contact) as reported in the RI Report (April, 1993).

[5] The cancer risk associated with bis(2–ethylhexyl)phthalate slightly exceeds the USEPA point of departure of $1x10^{-6}$ (at $4.6x10^{-6}$), but represents less than 3% of the total risk.

[6] Total risk is calculated for adults who consume fillets, are exposed to surface soil and sediment as adolescents, and use the groundwater for ingestion & other domestic purposes. For a child, total risk includes fillet ingestion, soil contact, and groundwater use.

NA= Not Applicable

EPC= Exposure Point Concentration

TABLE 6-52
SUMMARY OF NONCANCER RISK ESTIMATES
FUTURE LAND USE
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

EXPOSURE SCENARIO	ADULT		ADOLESCENT		CHILD		RISK CONTRIBUTIONS[1,2] (BY CHEMICAL)
	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	AVERAGE EPC	MAXIMUM EPC	
Ingestion of Pumpkinseeds	0.06	0.1	NA	NA	0.08	0.1	HIs[3]<1
Ingestion of Fillets (bullhead and pickerel)	0.07	0.1	NA	NA	0.09	0.1	HIs<1
Sediment Contact	NA	NA	0.2	1.0	NA	NA	Arsenic (1.0; skin)
Surface Soil Contact[4]	0.0006	0.001	NA	NA	0.004	0.007	HIs<1
Residential Groundwater Use (downgradient wells)							
Unfiltered	4	9	NA	NA	4	10	Manganese (4,9; CNS effects), Arsenic (0.3,1)
Filtered	4	9	NA	NA	5	10	Manganese (5, 10), Arsenic(<0.1,0.4)
Total Risk[5]							
Unfiltered	4	9	NA	NA	4	10	
Filtered	4	9	NA	NA	5	10	

Notes:

[1]Hazard indices for mixtures have been rounded to one significant figure while a hazard quotient for an individual chemical may have more than one significant figure.

[2]Hazard quotients for individual chemicals shown in parentheses, at average and maximum EPCs, respectively, for receptor showing greatest risk. *Toxicity endpoint of dose/response value also shown in parentheses.*

3HIs= hazard indices for mixtures.

[4] Risks for surface soil exposure (ingestion and dermal contact) as reported in the RI Report (April, 1993).

[5]Total risk is calculated for adults and children who consume fillets, are exposed to surface soil, and use the groundwater for domestic purposes.

NA= Not Applicable

[1]EPC= *Exposure Point Concentration*

TABLE 6-53
COMPARISON OF FISH EXPOSURE POINT CONCENTRATIONS
TO FDA ACTION LEVELS
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FDA ACTION LEVEL		WHOLE FISH (CONCENTRATIONS IN mg/kg)		FILLET (CONCENTRATIONS IN mg/kg)	
			AVERAGE CONCENTRATION	MAXIMUM CONCENTRATION	AVERAGE CONCENTRATION	MAXIMUM CONCENTRATION
DDE	5	(1)	0.083	0.17	0.012	0.021
DDD	5	(1)	0.12	0.23	0.019	0.050
Mercury	1	(2)	0.16	0.24	0.31	0.46

Notes:
COPCs not listed do not have FDA Action Levels
(1) In edible portion
(2) Methyl mercury in edible portion

TABLE 6-54
COMPARISON OF GROUNDWATER CONCENTRATIONS TO ARARs
COLD SPRING BROOK LANDFILL - DOWNGRADIENT WELLS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

COMPOUNDS	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION (ug/L)	ARITHMETIC AVERAGE CONCENTRATION (ug/L)	FEDERAL MCLs (ug/L)	MASS. MCLs (ug/L)	MASS. GUIDELINES (ug/L)	MASS. GROUNDWATER STANDARDS (ug/L)
UNFILTERED SAMPLES							
Semivolatile Organics							
Bis(2-ethylhexyl)phthalate	2/4	14	4	6	ND	6	3
Inorganics							
Aluminum	3/4	20500	3948.3	50-200 (1)	50-200 (5)	ND	ND
Arsenic	2/4	40	14	50	50	ND	50
Barium	4/4	112	41.1	2000	2000	ND	1000
Calcium	4/4	164000	69283.7	ND	ND	ND	"ND
Chromium	1/4	30.8	8	100	100	ND	50
Copper	2/4	31	11.4	1300 (2)	1300	ND	1000
Iron	4/4	25400	9593.6	300 (1)	300 (5)	ND	300
Lead	3/4	13.4	4.1	15 (2)	15	ND	50
Magnesium	4/4	28900	12293.8	ND	ND	ND	ND
Manganese	4/4	5700	2504.3	200/50 (3/1)	50 (5)	ND	50
Nickel	1/4	49	21.1	100	ND	100	ND
Potassium	4/4	8540	5554.4	ND	ND	ND	ND
Sodium	4/4	42900	18081.3	20000 (4)	ND	28000	20000
Vanadium	1/4	26.3	8.1	ND	ND	ND	ND
Zinc	1/4	60.1	19.5	11000/5000 (4/1)	5000 (5)	ND	5000
FILTERED SAMPLES							
Arsenic	1/3	19.8	4.9	50	50	ND	50
Barium	3/3	36.8	"NA	2000	2000	ND	1000
Calcium	3/3	148000	64473.3	ND	ND	ND	ND
Iron	2/3	14600	3156.8	300 (1)	300 (5)	ND	300
Magnesium	3/3	25000	11471.7	ND	ND	ND	ND
Manganese	3/3	6120	2983	200/50 (3/1)	50 (5)	ND	50
Potassium	3/3	17000	5930.8	ND	ND	ND	ND
Sodium	3/3	18600	13195	20000 (4)	ND	28000	20000
Vanadium	1/3	11.9	7.6	ND	ND	ND	ND

Notes:
Shaded line denotes either average or maximum (or both) concentration(s) of analyte exceeds at least one of the ARARs
NA = Not applicable ND = No value available
(1) Secondary maximum contaminant level (SMCL)
(2) Treatment technique
(3) Maximum contaminant level goal (MCLG)
(4) USEPA drinking water equivalency level (DWEL) - A lifetime exposure concentration protective of adverse, noncancer health effects that assumes all exposure is from a drinking water source
(5) Massachusetts SMCL

References:

USEPA, 1993. "Drinking Water Regulations and Health Advisories." Office of Water, Washington, D.C.; May, 1993.
MADEP, 1993. "Drinking Water Standards & Guidelines for Chemicals in Massachusetts Drinking Waters." Office of Research and Standards; Boston, MA; Spring, 1993.
MADEP, 1989. "Guidance for Disposal Site Risk Characterization and Related Phase II Activities - In Support of the Massachusetts Contingency Plan." Appendix C. Office of Research and Standards; Boston, MA; July, 1991 update.

Table 6-55
Comparison of Groundwater Concentrations to ARARs
Cold Spring Brook Landfill - Downgradient Wells

Remedial Investigation Addendum Report
Feasibility Study for Group 1A Sites
Fort Devens, MA

COMPOUNDS	FREQUENCY OF DETECTION	MAXIMUM DETECTED CONCENTRATION (ug/L)	ARITHMETIC AVERAGE CONCENTRATION (ug/L)	FEDERAL MCLs (ug/L)	MASS. MCLs (ug/L)	MASS. GUIDELINES (ug/L)	MASS. GROUNDWATER STANDARDS (ug/L)
UNFILTERED SAMPLES							
Semivolatile Organics							
Bis(2-ethylhexyl)phthalate	2/4	14	4	6	ND	6	3
Inorganics							
Aluminum	3/4	20500	3948.3	50-200 (1)	50-200 (5)	ND	ND
Arsenic	2/4	40	14.0	50	50	ND	50
Barium	4/4	112	41.1	2000	2000	ND	1000
Calcium	4/4	164000	69283.7	ND	ND	ND	ND
Chromium	1/4	30.8	8.0	100	100	ND	50
Copper	2/4	31	11.4	1300 (2)	1300	ND	1000
Iron	4/4	25400	9593.6	300 (1)	300 (5)	ND	300
Lead	3/4	13.4	4.1	15 (2)	15	ND	50
Magnesium	4/4	28900	12293.8	ND	ND	ND	ND
Manganese	4/4	5700	2504.3	200/50 (3/1)	50 (5)	ND	50
Nickel	1/4	49	21.1	100	ND	100	ND
Potassium	4/4	8540	5554.4	ND	ND	ND	ND
Sodium	4/4	42900	18081.3	20000 (4)	ND	28000	20000
Vanadium	1/4	26.3	8.1	ND	ND	ND	ND
Zinc	1/4	60.1	19.5	11000/5000 (4/1)	5000 (5)	ND	5000
FILTERED SAMPLES							
Arsenic	1/3	19.8	4.9	50	50	ND	50
Barium	3/3	36.8	NA	2000	2000	ND	1000
Calcium	3/3	148000	64473.3	ND	ND	ND	ND
Iron	2/3	14600	3156.8	300 (1)	300 (5)	ND	300
Magnesium	3/3	25000	11471.7	ND	ND	ND	ND
Manganese	3/3	6120	2983	200/50 (3/1)	50 (5)	ND	50
Potassium	3/3	17000	5930.8	ND	ND	ND	ND
Sodium	3/3	18600	13195	20000 (4)	ND	28000	20000
Vanadium	1/3	11.9	7.6	ND	ND	ND	ND

Shaded line denotes either average or maximum (or both) concentration(s) of analyte exceeds at least one of the ARARs

NA = Not applicable ND = No value available
(1) Secondary maximum contaminant level (SMCL)
(2) Treatment technique
(3) Maximum contaminant level goal (MCLG)
(3) Maximum contaminant level goal (MCLG)
(4) USEPA drinking water equivalency level (DWEL) - A lifetime exposure concentration protective of adverse, non-cancer health effects that assumes all exposure is from a drinking water source
(5) Massachusetts SMCL

References:

USEPA, 1993. "Drinking Water Regulations and Health Advisories." Office of Water, Washington, D.C.; May, 1993.
MADEP, 1993. "Drinking Water Standards & Guidelines for Chemicals in Massachusetts Drinking Waters." Office of Research and Standards; Boston, MA; Spring, 1993.
MADEP, 1989. "Guidance for Disposal Site Risk Characterization and Related Phase II Activities - In Support of the Massachusetts Contingency Plan." Appendix C. Office of Research and Standards; Boston, MA; July, 1991 update.

7.0 BASELINE ECOLOGICAL RISK ASSESSMENT

This section presents the results of the supplemental ERA for the Shepley's Hill Landfill and Cold Spring Brook Landfill sites. The Supplemental Risk Assessment was performed to update the original ERA, which was included as Section 9 of the RI report (E&E, 1993). The supplemental ERA integrates information gathered from several phases of site investigation at the Group 1A sites to establish whether environmental contaminants may pose a risk to ecological receptors. Specifically, this supplemental risk assessment evaluates sediment and fish tissue analytical data, and macroinvertebrate community data that were unavailable when the RI report was produced. In addition the supplemental risk assessment also includes a re-analysis of surface water data presented in the original RI report. The data were evaluated to determine the potential for adverse environmental effects to ecological receptors resulting from contaminant exposure. No additional evaluation of surface soils or groundwater is included in the supplemental risk assessment.

The primary conceptual approach employed in this supplemental risk assessment, as well as in the RI risk assessment, is ecological pathway analysis. Pathways evaluated include portions of food chains (e.g., sediment → primary consumer → secondary consumer → tertiary consumer). Because the modeling presented in the RI risk assessment used little actual environmental data, additional field and laboratory data were collected prior to conducting this supplemental risk assessment. These additional data refine and help to reduce uncertainties inherent in the ERA process.

The general objectives and scope of the Supplemental Risk Assessment are presented in this subsection. Following this subsection, separate subsections are provided to evaluate risks at the Shepley's Hill Landfill (Subsection 7.1) and the Cold Spring Brook Landfill (Subsection 7.2). A discussion of uncertainties inherent in the risk assessment process is presented in Subsection 7.3, and Subsection 7.4 summarizes the results of the supplemental risk assessments. The supplemental risk assessment for each landfill consists of the following six elements:

- Introduction
- Hazard Assessment

- Ecological Characterization
- Ecological Exposure Assessment
- Ecological Effects Assessment
- Ecological Risk Characterization

The supplemental risk assessment was performed in accordance with the following guidance documents:

- Risk Assessment Guidance for Superfund (RAGS): Volume 2 - Environmental Evaluation Manual (USEPA, 1989d);

- Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference (USEPA, 1989a);

- USEPA Region I Supplemental Risk Assessment Guidance for the Superfund Program, Part 2, Guidance for Ecological Risk Assessments (USEPA, 1989c);

- Ecological Assessment of Superfund Sites: An Overview (USEPA, 1991h); and

- Framework for Ecological Risk Assessment (USEPA, 1992e).

In addition, recent risk assessment guidance including the USEPA "Eco Update" bulletins (USEPA 1991b, 1992a, 1992b) and publications (Maughan 1993; Suter, 1993) were used as guidance for this supplemental risk assessment.

7.1 SHEPLEY'S HILL LANDFILL

The supplemental risk assessment for the Shepley's Hill Landfill is provided in the following subsections. This revision to the RI risk assessment (E&E, 1993) includes relevant information obtained through recent studies at the Group 1A sites. A primary objective of the Shepley's Hill Landfill supplemental risk assessment is to evaluate the potential for adverse environmental effects resulting from exposure to analytes found in fish tissue and sediments in Plow Shop Pond, a water body adjacent to the landfill. Specifically, the supplemental risk assessment for the Shepley's Hill Landfill evaluates fish tissue analytical data and aquatic

macroinvertebrate community data that were unavailable when the original RI report was produced. This assessment also includes a re-analysis of surface water data presented in the original RI report. No additional evaluation of surface soils or groundwater is included in this supplemental risk assessment.

7.1.1 Summary of the RI Risk Assessment

The RI risk assessment indicated that concentrations of copper, silver, zinc, and iron in different regions of Plow Shop Pond exceeded available surface water screening criteria. However, because the presence of these analytes in surface water was not attributable to the Shepley's Hill Landfill, they were not considered as COPCs in the risk assessment. Inorganic analytes in groundwater were considered in the RI risk assessment to evaluate exposure to vegetation growing in areas where roots may be exposed to groundwater. Because the landfill is capped, surface soils were not evaluated in the RI risk assessment.

Although a number of analytes in Plow Shop Pond sediments were found to be above background levels, only arsenic, barium, cadmium, and manganese were considered in the ERA in the original RI report (E&E, 1993). These analytes were evaluated because of the interpretation that their spatial distribution indicated they originated at the Shepley's Hill Landfill. Analytes not evaluated included mercury, chromium, lead, nickel, and zinc. The contribution from these five and other analytes was not evaluated because they were not considered to be site-related (i.e., they originated in a source other than Shepley's Hill Landfill).

The RI risk assessment indicated that sediment contamination from the landfill-derived inorganic analytes in Plow Shop Pond may pose a risk to ecological receptors. Arsenic was found to be the primary risk contributor to aquatic and semi-aquatic biota. Risks to aquatic biota were also predicted from cadmium. Although barium and manganese also occur at elevated levels in Plow Shop Pond and may affect the pond's biota, the ecological risk from these analytes was not defined in the RI risk assessment.

A summary of the RI risk assessment findings relative to Plow Shop Pond surface water, sediment, and landfill groundwater is presented in Table 7-1. Additional detail regarding the site history, its setting, and the nature of previous investigations can be found in the RI report (E&E, 1993) and in earlier sections of this report.

7.1.2 Conceptual Site Model

In accordance with recent USEPA guidance (USEPA, 1992e), a conceptual model has been developed to evaluate how chemical stressors from the Shepley's Hill Landfill may impact ecological components of the environment in the vicinity of the site (Figure 7-1). This model involves consideration of the ecological community primarily at risk (Plow Shop Pond), stressor characteristics, and exposure pathways. The exposure scenarios evaluated in the conceptual model consider sources, environmental transport mechanisms, partitioning of the analytes between various environmental media, identification of exposure routes, and the types of ecological receptors that could be potentially exposed.

Ecological receptors evaluated in this supplemental risk assessment include aquatic biota (i.e., plants, invertebrates, fish, and amphibians) and semi-aquatic biota (i.e., wildlife that depend on wetlands to meet a portion of their life history requirements). Effects evaluated in the supplemental risk assessment are generally the observed, estimated, or predicted effects of the COPCs on the survival, growth, and reproduction of receptors.

A significant difference between the supplemental risk assessment and the original RI risk assessment is related to the selection of surface water and sediment analytes for evaluation in the Shepley's Hill Landfill risk assessment. The original risk assessment only evaluated ecological risk from four inorganic analytes thought to be attributable to the landfill. As detailed in Subsection 7.1.3, this supplemental risk assessment evaluates risk from analytes that clearly originated at the Shepley's Hill Landfill, as well as the risks associated with ecological exposures to all analytes that were not eliminated during the contaminant screening process (Subsection 7.1.3.1). Based on information contained in Section 4.0 and the original RI report (E&E, 1993), sediment contaminants that originated in the Shepley's Hill Landfill are arsenic, barium, iron, manganese, and nickel.

7.1.3 Supplemental Risk Assessment

7.1.3.1 Hazard Assessment. Sampling conducted as part of the RI and supplemental RI at the Shepley's Hill Landfill has revealed the presence of organic and inorganic analytes in the following environmental media:

- Plow Shop Pond Surface Water
- Plow Shop Pond Sediments
- Plow Shop Pond Fish Tissue
- Groundwater

Analytical data for surface water, sediment, and fish tissue are evaluated in this supplemental risk assessment. No additional consideration of groundwater is included in this report.

Selection of Contaminants of Potential Concern (COPCs). Pursuant to USEPA (1989d) guidance, the surface water, sediment, and fish tissue analytical data were evaluated to determine their validity for use in risk assessment. All validated data from the RI field investigation were sorted by medium and summarized. Non-detects were assigned one-half the SQL for calculation of average (i.e., arithmetic mean) concentrations. The selection of COPCs is a screening process used to identify the analytes requiring evaluation in the risk assessment. Factors considered when selecting COPCs at the Shepley's Hill Landfill included: the suitability of the data for ERA; the physical-chemical properties of analytes; the frequency of detection; the potential for bioaccumulation and bioconcentration; and the inherent toxicity of the analytes (USEPA, 1989b, 1991). Inorganic compounds such as calcium, magnesium, potassium, and sodium were generally excluded from consideration as COPCs because they are essential dietary nutrients and are considered toxic to aquatic and semi-aquatic ecological receptors only at high concentrations (USEPA, 1989d). A general representation of the process used to select COPCs is presented in the following paragraphs.

The data from each site were evaluated independently to determine: (1) which detected analytes are believed to be site-related, and (2) which data are of sufficient quality for use in quantitative risk assessment. The individual steps involved in the COPC selection process are briefly discussed below.

- <u>Sort Data by Medium</u>. Data from the RI and Supplemental RI Group 1A investigations were compiled and sorted by environmental medium (i.e., surface water, sediment, and fish tissue). All analytes detected in at least one sample in each medium were identified.

- <u>Evaluate the Quality of the Data</u>. Based on results of the data evaluation (see Subsection 2.5.2.6), overall quality of the data were

reviewed to determine which data were of sufficient quality for use in quantitative risk assessment. This review was conducted in accordance with USEPA guidance (USEPA, 1989c, 1989d, and 1992h). The analytical data determined to be suitable for use in risk assessment were summarized by medium.

- Background Comparison. Although typically a component of the COPC selection process, because no background surface water, sediment, or fish tissue databases exist for Fort Devens, no comparison to background was conducted in this supplemental ERA.

- Develop a Data Set for Use in Risk Assessment. The analytical data used to select COPCs and to conduct the risk assessment were summarized in COPC tables. Each medium-specific table contains the following information: (1) list of all analytes detected in at least one sample; (2) frequency of detection; (3) average analyte concentration; (4) identification of those analytes selected as COPCs; and (5) the rationale for excluding those analytes which were not selected as COPCs.

- Comparison With Background. Although typically a component of the COPC selection process, a comparison to background was not conducted because no background surface water, sediment, or fish tissue database exists for Fort Devens.

In selecting COPCs for ecological risk at the Fort Devens Sites, the following USEPA guidelines were used (USEPA, 1989d):

- COPCs include analytes that were positively identified in at least one sample;

- COPCs include analytes that were detected at levels significantly elevated above blank concentrations, as determined in Sections 2.0 and 4.0);

- When evaluating common laboratory contaminants (acetone, 2-butanone, methylene chloride, and phthalate esters), the COPCs

were selected based on the evaluation of laboratory contaminants presented in Section 4.0 and based on USEPA (1989d) guidance;

- Analytes were generally eliminated as COPCs if their frequency of detection was five percent or less;

- The essential nutrients sodium, potassium, magnesium, calcium were generally eliminated as COPCs for ecological risk assessments (USEPA, 1989d);

- No analyte was eliminated from the COPCs list if the maximum concentration exceeded an ARAR or guidance value (e.g. USEPA Interim Sediment Quality Criteria); and,

- No analyte was eliminated from the COPC list if it is a transformed or parent compound of a COPC.

Surface Water COPCs. The RI risk assessment summarized analytical data from 15 surface water samples, including 13 from Plow Shop Pond, one from the palustrine wetland north of the landfill, and one from Nonacoicus Brook just below the dam retaining Plow Shop Pond. In the RI risk assessment, chemicals selected for evaluation included only those analytes that were believed to have originated from Shepley's Hill Landfill (i.e., arsenic, barium, cadmium, and manganese).

Surface water is re-evaluated in this supplemental assessment to provide an indication of the overall risk to aquatic life from exposure to both landfill related and non-related analytes detected in surface water. Because no background Fort Devens surface water data are available, no analytes detected in surface water could be eliminated as COPCs based on a comparison to background. Major cations (e.g., calcium, magnesium, potassium, and sodium) were eliminated as COPCs because they are essential dietary nutrients and are generally considered to be of low toxicity. Although iron is an essential nutrient, it was retained as a COPC in surface water because it is a suspected landfill contaminant.

Four organic analytes (alpha-BHC, chloroform, endrin, and methylene chloride) were detected in Plow Shop Pond surface water during the RI. However, the validity of the organic data is questionable (see Section 4.1.3). The concentrations

of alpha-BHC presented in the original RI report were footnoted to reflect that these "results were not confirmed on a second column;" therefore, these data are considered suspect and this analyte was eliminated as a COPC. Endrin was detected in only one of the 15 surface water samples at a concentration equal to the reported detection limit (0.008 μg/L); therefore, it was eliminated as a COPC. Methylene chloride was detected in all samples analyzed. However, this analyte is a known laboratory contaminant and was not a COPC in groundwater and therefore was eliminated as a COPC in surface water.

An uncertainty associated with the evaluation of the E&E (1993) surface water data is associated with the use of samples analyzed for total, rather than dissolved, analytes. Recent USEPA national guidance recommends that dissolved contaminant data be used for ecological risk assessments evaluating surface water. Dissolved contaminant data better represent the bioavailable fraction of analytes present in surface water. Therefore, the use of total contaminant surface water data (rather than the dissolved fraction) may result in an over-estimate of risk associated with surface water exposures by aquatic organisms at the Group 1A sites.

Surface water COPCs for the Shepley's Hill Landfill site are presented in Table 7-2.

Sediment COPCs. The RI Risk Assessment summarized analytical data from 15 shallow sediment samples from Plow Shop Pond and the palustrine wetland located to the north of the landfill (the Nonacoicus Brook wetland). Thirteen of these samples were collected in Plow Shop Pond, and two were collected in the wetland. These shallow sediment samples were collected with an Ekman dredge from approximately the top 6 inches of pond sediment. (Appendix X contains an ecological Preliminary Risk Evaluation (PRE) of the Nonacoicus Brook wetland area, located to the north of the landfill.)

Sediment samples from 28 additional locations were collected by ABB-ES in November and December of 1992 (see Section 2.0). This sediment sampling in Plow Shop Pond was conducted with vibratory coring techniques and provided samples from the top 12 inches of pond sediment.

Ecological exposure to contamination in Plow Shop Pond is likely to be greatest in the top 6 inches of pond sediments. It is unlikely that significant ecological

exposure to either floral or faunal receptors occurs in the anoxic interval between 6 and 12 inches. However, in order to best characterize the ecological exposure at the Group 1A sites, and in accordance with an October 20, 1993 Army agreement with state and federal regulators, the 13 shallow sediment and the 28 zero- to 12-inch sediment samples were combined to yield a total of 41 sediment samples. The maximum and average concentrations from the pooled data set serve as the ecological exposure point concentrations. In general, the 13 sediment samples collected between the zero- and six-inch interval contain higher maximum concentrations of inorganics than the 28 more recently analyzed samples. The five inorganic COPCs evaluated in this report (i.e., arsenic, barium, iron, manganese, and nickel) were detected with similar frequency in both the original RI (E&E, 1993) and the ABB-ES 1992 sampling event data sets. With the exception of manganese, these inorganic analytes were detected at higher concentrations in the original data set. A similar trend was observed for the majority of the other organic and inorganic COPCs analyzed during both phases of investigation. However, the pesticides DDT, DDE, and DDD, as well as zinc were detected at higher frequencies in the ABB-ES data set. This may be related to the generally lower detection limits achieved for these analytes in the more recent ABB-ES studies. In addition, the more recently collected samples were not analyzed for VOCs or SVOCs, although the original 13 samples were analyzed for these constituents. Evaluating the combined data set consisting of 41 samples generally produces a more representative estimate of average sediment exposure point concentrations.

Although a number of analytes were found at elevated concentrations in Plow Shop Pond sediments, only arsenic, barium, cadmium, and manganese were considered in the RI ERA (E&E, 1993). These analytes were evaluated because their spatial distribution suggested that the Shepley's Hill Landfill was a primary source of these sediment constituents. Analytes that potentially originated in a source(s) other than Shepley's Hill Landfill were not evaluated in the RI ERA.

Because of regulatory concerns regarding the ecological risk contributions from analytes not evaluated in the original RI report, this supplemental risk assessment presents two levels of risk evaluation from contaminated sediments. To evaluate the landfill contribution to sediment contamination in Plow Shop Pond, an evaluation of analytes that clearly originated at the Shepley's Hill Landfill has been conducted. Based on information contained in Section 4.0 and the RI report (E&E, 1993), analytes interpreted to be from the landfill are arsenic, barium, iron,

manganese, and nickel. Cadmium has been removed from the list of landfill contaminants because the RI Addendum sampling activities have indicated that it is not a landfill contaminant. Iron and nickel have been added as COPCs because they are suspected landfill-related contaminants. In addition, to evaluate total risk from Plow Shop Pond sediments, an evaluation of all analytes that were retained as COPCs is also included in this supplemental risk assessment. Analytes of concern other than those directly attributable to the Shepley's Hill Landfill include pesticides/PCBs, PAHs and a number of additional inorganics.

The COPCs selected for the Shepley's Hill Landfill ecological risk assessment differ slightly from those selected for the public health assessment. For instance, for the public health assessment all PAHs were selected as COPCs regardless of the frequency of detection. This was done primarily due to human health concerns regarding the potential carcinogenicity of PAHs. In general, for the ecological risk assessment, only those PAHs detected in greater than 5% of the samples were selected as COPCs.

As discussed in the RI Report (E&E, 1993) for the original RI risk assessment, the inorganic COPCs in sediments were compared to background soil concentrations because no background sediment database was available. Average and maximum concentrations of the four original risk assessment landfill analytes (arsenic, barium, cadmium, and manganese) exceeded the upper tolerance limits on their respective Fort Devens background soil concentrations. However, because of regulatory concerns regarding the validity of using soils data as a means of screening inorganic analytes in sediment samples, and because no sediment background database has been established and agreed to at Fort Devens, no screening against background has been included in this supplemental risk assessment.

Plow Shop Pond sediment COPCs are presented in Table 7-3.

Fish COPCs. Fish sampling and analysis was conducted as described in Section 2.0. Whole fish and fillet tissue burdens were obtained for all three species of fish analyzed: bluegill (whole fish only), bullhead, and largemouth bass. Results were reported for suspected landfill and non-landfill analytes. All results were reported on a wet weight basis. The percentage of water in fish samples ranged from 66 to 88 percent. The ERA only evaluates the results of the whole body tissue analyses, as these data are most appropriate for evaluating ecological

exposures and risks. Fish fillet samples were collected for the purpose of assessing risks to public health (Section 6.0).

Summary statistics were calculated to evaluate concentrations of inorganic analytes in all 15 (five each of bluegill, bullhead, and largemouth bass) whole fish sampled and analyzed from Plow Shop Pond (Table 7-4). Table 7-4 also presents a summary of organic and inorganic COPCs in each of the three fish species evaluated at Plow Shop Pond.

Six inorganic analytes (antimony, beryllium, nickel, silver, thallium, and vanadium) were not detected in any Plow Shop Pond whole body fish tissues analyzed. Barium, calcium, copper, iron, magnesium, manganese, mercury, selenium, sodium, and zinc were detected in all whole fish tissues analyzed. A total of four pesticides/PCBs were detected in the 15 whole fish sampled in Plow Shop Pond. The sole PCB detected, Aroclor-1260, was found in five of the 15 fish sampled at an average concentration of 0.062 $\mu g/g$ wet weight and a maximum concentration of 0.33 $\mu g/g$ wet weight. The pesticide DDT, and its breakdown products DDE and DDD were found in 1, 11, and 6 of the 15 fish (all largemouth bass) analyzed, respectively. The maximum pesticide concentration detected was 0.42 $\mu g/g$ wet weight (DDE in a largemouth bass), while the average pesticide concentrations in all fish ranged from 0.0055 (DDT) to 0.068 (DDE) $\mu g/g$ wet weight.

The fish tissue contaminant burden at Plow Shop Pond was evaluated through empirical and statistical comparisons of Plow Shop Pond whole fish tissue data with data from regional and national studies of fish tissue contaminant burden. Sources of information reviewed to establish "background" or naturally occurring tissue levels of certain inorganics and pesticides/PCBs within Massachusetts include information from various programs (e.g., Clean Lakes Program) of the MADEP, Division of Water Pollution Control ([MADWPC], 1988a; 1988b; 1989a; 1989b; 1990; 1991). While this regional source of information is a useful screening tool, it is important to recognize that there are no MADWPC average data available to evaluate several fish tissue COPCs, including arsenic, barium, and cadmium. To compare Plow Shop Pond Fish tissue data to a national database, information from the United States Fish and Wildlife Service [USFWS] National Contaminant Biomonitoring Program (NCBMP) was reviewed (Schmitt et al., 1990; Schmitt and Brumbaugh, 1990).

A detailed evaluation of Plow Shop Pond fish tissue concentrations relative to regional and national sources of "background" information is presented in Appendix N. Table 7-5 summarizes this evaluation.

Average concentrations of aluminum, iron, manganese, and zinc in fish from Plow Shop Pond were significantly higher than average tissue concentrations for all fish representing all trophic levels in the MADWPC database (Figure N-1). No other statistically significant differences were noted between Plow Shop Pond fish and the regional source of information. Levels of mercury in largemouth bass surpassed levels reported from both regional and national sources of information. While average concentrations of mercury in bluegill were below the regional estimates for this analyte, the maximum concentration detected in bluegill was higher than the 85th percentile concentration in the nationwide database. Both average and maximum concentrations of mercury in largemouth bass and bullhead exceeded regional and national reported levels.

The pesticide DDE was detected in all species of fish collected from Plow Shop Pond, as well as in a number of fish in the MADWPC data. Although fish tissue concentrations of this analyte did not exceed any national levels, DDE concentrations in largemouth bass were slightly greater than regional levels reported by MADWPC for all fish representing all trophic levels. This difference was not statistically different. Average arsenic concentrations in bluegill and bullhead both exceeded the national levels; however, arsenic was not detected in largemouth bass. No data regarding "background" arsenic concentrations in fish tissue were available from MADWPC.

Cadmium was detected in one largemouth bass from Plow Shop Pond. This analyte was undetected in the regional information sources of the MADWPC. The concentration of cadmium in the one bass was slightly above the national 85th percentile concentration.

Average iron and manganese concentrations in bluegill, largemouth bass, and bullhead from Plow Shop Pond were higher than their respective average concentrations in the MADWPC database for all fish representing all trophic levels. In general, the lower trophic level fish species evaluated (i.e., the bluegill) contained higher average concentrations of these two inorganics than did higher trophic level species (i.e., the largemouth bass).

Target analytes known to bioconcentrate in fish tissue include cadmium, mercury, and various organochlorinated pesticides and PCBs. In general, higher concentrations of all bioconcentratable analytes were detected in higher trophic level piscivorous fish (e.g., the largemouth bass) from Plow Shop Pond than in lower trophic level fish (e.g., the bluegill). Cadmium and a PCB (Aroclor-1260) were detected in bass, but not in bluegill or bullheads. Although mercury was detected in all three species of fish analyzed, the highest concentrations were detected in the largemouth bass.

7.1.3.2 Ecological Characterization. The purpose of the ecological characterization is to describe the habitats and potential ecological receptor species that may be exposed to COPCs associated with the Shepley's Hill Landfill. The presence of rare, threatened, and endangered receptors within (and adjacent to) the study area is also included in this subsection. This characterization is based on earlier descriptions of the site ecology in the RI report, as well as on information collected since the original RI was completed. The information included in this section is used as the basis for identification of relevant exposure pathways and the selection of appropriate indicator species in the ecological exposure assessment.

Site Description: Shepley's Hill Landfill. An ecological characterization of the Shepley's Hill Landfill was conducted as part of the original RI field investigation (E&E, 1993). This characterization included the identification of plant and animal communities known to be present at the site, and observations of any actual or potential effects of site contaminants on the site's ecological resources. A summary of the major habitat types identified during the RI at the Shepley's Hill Landfill is presented in Table 7-6. A primary focus of the supplemental risk assessment is to evaluate risk to ecological receptors in Plow Shop Pond; therefore, a summary of the major wetland habitat types and dominant plant species associated with this pond is presented below.

<u>Forested Wetland</u>. Forested wetland habitat is located on the northeastern boundary of the landfill, downgradient from groundwater flow from the landfill. One region of forested wetland habitat is located at the junction of Nonacoicus Brook and Plow Shop Pond, while the other consists of the narrow strip of wetland that borders Plow Shop Pond. Both forested wetlands are dominated by red maple (*Acer rubrum*), with shrubs such as nannyberry (*Viburnum lentago*),

highbush blueberry (*Vaccinium corymbosum*), and silky dogwood (*Cornus amomum*) in the sub-story.

Emergent/Open Water Wetland. The waters of Plow Shop Pond are designated as Class B by the Commonwealth of Massachusetts. The pond is eutrophic, and was classified in the original RI as a floating-leaved deep marsh. Seasonally, more than 80 percent of the surface area of the pond is covered with aquatic macrophytes, including sweet water lily (*Nymphaea odorata*) and water shield (*Brasenia schreberi*). Submerged macrophytes (primarily water marigold [*Megalodonta beckii*]), seasonally cover more than 75 percent of the submerged portions of the pond.

A Wetland Evaluation Technique (WET) evaluation was conducted on Plow Shop Pond to assess the functions and values of this wetland. WET is a standardized evaluation technique that provides a rapid assessment of many of the recognized values and functions of a wetland (Adamus et al., 1991). WET uses a standardized manual and answer sheet to provide input data for the WET 2.0 computer program. After data are entered into the WET program, a "Low," "Medium," or "High" value is assigned to each function.

A combination of the following 11 functions (i.e., physical, chemical, and biological characteristics) and values (characteristics beneficial to society) were evaluated through WET at Plow Shop Pond:

- Groundwater Recharge
- Groundwater Discharge
- Floodflow Alteration
- Sediment Stabilization
- Sediment/Toxicant Retention
- Nutrient Removal/Transformation
- Production Export
- Wildlife Diversity/Abundance
- Aquatic Diversity/Abundance
- Uniqueness/Heritage
- Recreation

The above-listed functions and values were evaluated by WET in the following contexts: "Social Significance" (the value of the wetland to society); "Effectiveness"

(the capability of the wetland to provide the function); and "Opportunity" (the opportunity of the wetland to provide the function).

The WET analysis determined that the value to society of Plow Shop Pond is "high" for Groundwater Recharge, Groundwater Discharge, Wildlife Diversity and Abundance, and Uniqueness and Heritage. The remainder of the evaluated WET parameters were rated as "low" to "moderate" in social significance. In terms of effectiveness, WET scored Plow Shop Pond as "high" for Sediment/Toxicant Retention and Wildlife Breeding and Migration, and as "low" to "moderate" for the other functions and values in WET. Of the three functions/values evaluated for Opportunity, the opportunity for Plow Shop Pond to perform the Sediment/ Toxicant Retention and Nutrient Removal/Transformation functions is rated as "high" by WET. Plow Shop Pond has the opportunity to provide these functions because the proximity of the adjacent landfill. Floodflow Alteration is rated as "moderate" by WET based upon the high percentage of the watershed this wetland occupies.

The WET functional assessment is included as Appendix O. In addition, this appendix includes a detailed narrative discussion interpreting the results of the WET analysis.

Rare, Threatened, and Endangered Species. The presence or absence of rare and endangered flora and fauna at the site is reviewed in this subsection. Under contract to the U.S. Army Corps of Engineers, ABB-ES has developed a database of all flora and fauna known to seasonally or permanently occur at Fort Devens (ABB-ES, 1992). Particular emphasis has been paid to rare and endangered biota (the term "rare and endangered" refers to those species with protected status under the Federal Endangered Species Act [FESA] of 1973, as amended in 1988, and the Massachusetts Endangered Species Act [MESA] of 1990). The Fort Devens biological database contains current information from the MNHP and the USFWS regarding all rare and endangered species known to occur at Fort Devens. In addition, the ABB-ES database contains records that have not yet been incorporated into the MNHP database.

The ABB-ES master biological database has been checked for known occurrences of rare and endangered biota in the vicinity of Shepley's Hill Landfill. Records for the following species are known to exist in the vicinity of the landfill: grasshopper sparrow (*Ammodramus savannarum*) and upland sandpiper

(*Bartramia longicauda*). In addition, a Cooper's hawk (*Accipiter cooperii*) was identified during the initial phase of ecological characterization at the landfill (E&E, 1993). These three species are primarily considered upland species with minimal potential exposure to contaminated sediments in Plow Shop Pond. Therefore, it is unlikely that any of these receptors are at risk from environmental contamination at Plow Shop Pond.

Fish Community Study. As a supplemental RI activity, ABB-ES conducted a qualitative study of the fish population at Plow Shop Pond. The fish evaluation was designed to provide baseline information regarding the species of fish present, relative abundance of the species present, fish size distribution, trophic structure of the fish community, and the presence or absence of recreationally important fish. The fish evaluation was not intended to provide an inventory or survey of all fish present in the ponds, but to serve as a means of gathering baseline information regarding the Plow Shop Pond fishery. The fish sampling program is described in the Section 2.0. Appendix N contains an evaluation of the fish size distribution in Plow Shop Pond, as well as an evaluation of fish tissue contaminant concentrations relative to sources of "background" information.

A total of 193 fish representing seven families and 12 species were collected in Plow Shop Pond (Table 7-7 and Figure 7-2). Approximately 65 percent of the fish were captured via electrofishing; the remainder were captured via gill and trap netting (Figure 7-3). Although relatively few animals (n = 50) were captured via trap netting, the only record for one species, the white perch (*Morone americana*), was obtained via this method. Gill netting, electroshocking, and use of trap nets successfully resulted in the capture of chain pickerel, golden shiner, and bluegill.

The bluegill (*Lepomis macrochirus*) dominated the fish community sampled in terms of total numbers and total weight. Sunfish (members of the family Centrarchidae) accounted for more than 75 percent of the total number of fish captured in Plow Shop Pond, and for more than 60 percent of the total fish biomass sampled. In addition to the bluegill, other species of sunfish collected in Plow Shop Pond included the pumpkinseed (*Lepomis gibbosus*), black crappie (*Pomoxis nigromaculatus*), and the largemouth bass (*Micropterus salmoides*).

Top predators, including the largemouth bass and chain pickerel (*Esox niger*) represented more than 10 percent of the total numbers of animals collected. One possible young-of-the-year largemouth bass was collected (71 mm), suggesting that

this predator has successfully spawned in the Plow Shop Pond drainage. Two of the five largemouth bass collected in Plow Shop Pond were large (i.e., in excess of 3.5 kg).

Five insectivorous species (three bullhead [*Ictalurus*] species, pumpkinseed, and bluegill), and five insectivore/piscivore species (largemouth bass, white perch, black crappie, American eel, and yellow perch) were found in the pond. The insectivore/piscivore guild represented more than 80 percent of the total sample population. The golden shiner (*Notemigonus crysoleucas*), an omnivore, represented approximately 7 percent of the fish population, whereas the chain pickerel, a piscivore, represented about 9 percent of the Plow Shop Pond fish community.

Based on the limited data obtained in this study, the species composition and taxa richness of Plow Shop Pond appears to be typical of a southern New England warm water fish community. The numbers of individual fish collected at Plow Shop Pond was typical of sampling efforts in small lake habitats throughout southern New England (Downey, 1993). However, it is unknown whether the relatively low contribution of bass in the 1 kg range and the high percentage of bass greater than 1 kg reflect the limitations of a one-time sampling effort or is truly representative of the fish community at Plow Shop Pond.

Macroinvertebrate Study. The macroinvertebrate program at the Fort Devens Group 1A sites was designed to provide baseline information regarding the biota associated with aquatic habitats at Plow Shop Pond and Cold Spring Brook Pond, and to provide baseline information for possible use in evaluation of effects and effectiveness of any future remedial actions. When considered in conjunction with other ecological studies, results obtained from macroinvertebrate studies can be used to characterize the existence and extent of ecological impairments, evaluate the effectiveness of remedial actions, and provide a baseline characterization of biotic components of wetlands and aquatic systems (Plafkin et al., 1989).

Because the macroinvertebrate community data from Plow Shop Pond and Cold Spring Brook Pond were analyzed concurrently, the following discussion presents summary information for both potentially impacted ponds, although it concentrates on Plow Shop Pond. Additional detail regarding the macroinvertebrate sampling program at Cold Spring Brook Pond can be found in Subsection 7.2.3.2, and in Appendix P.

In response to regulatory input (USEPA and MADEP, 1993), the following objectives were considered for this macroinvertebrate study:

- to determine the presence or absence of macroinvertebrate infauna;
- to gather information about population density and taxonomic diversity;
- to statistically evaluate the relationship between the macroinvertebrate community characteristics of the potentially impacted ponds and the concentrations of analytes found in the sediment.

The macroinvertebrate sampling and analysis program was designed to meet these objectives. However, as discussed elsewhere (i.e., ABB-ES, 1993a and Subsection 7.3), considerable uncertainty is associated with the interpretation of the results of the Group 1A macroinvertebrate study. Limited numbers of samples, uncertainties associated with the selected reference pond, differences in habitat types between ponds, and natural environmental stochasticity confound interpretation of this portion of the supplemental risk assessment.

A semiquantitative inventory of macroinvertebrates was conducted at three sampling stations in Plow Shop Pond (Figure 2-1) and New Cranberry Pond (Figure 2-10). At each sampling station, two duplicate macroinvertebrate samples from vegetation ("phytomacrofauna") and two duplicate samples from sediment ("benthic infauna") were collected. Sampling of the macroinvertebrate community is described in the Data Gap Activities Section (Section 2.0).

Information regarding the physical attributes of the aquatic habitat (including nature of the substrate and vegetative characteristics) and water quality parameters (i.e., dissolved oxygen, temperature, pH, and conductivity) were collected at each sampling station and are summarized in Table 7-8.

A number of ponds on the South Post were considered as reference stations for the macroinvertebrate study. To select an appropriate reference pond, input was solicited from USEPA, USFWS, and MADEP. Of the South Post ponds reviewed, New Cranberry Pond most closely resembled Plow Shop Pond and Cold Spring Brook Pond in terms of ecological characteristics and trophic state.

Therefore macroinvertebrate (benthic and phytomacrofaunal) and sediment samples were collected from three macroinvertebrate sampling stations at New Cranberry Pond. A summary of the analytical data from shallow sediment samples collected from macroinvertebrate sampling stations at Plow Shop Pond and New Cranberry Pond is presented in Table 7-9.

An analysis of New Cranberry Pond sediment chemistry data from the macroinvertebrate sampling stations indicates that lead, mercury, DDT, DDE, and DDD may exceed available sediment quality criteria and guidance values (Table 7-10). It is possible that some or all of these exceedances represent a "background" level of analytes (particularly pesticides) on South Post, rather than a hazardous waste site-related problem. Furthermore, it is possible that the pesticide sediment quality criteria are overly conservative for use at Fort Devens (see Appendix S).

Based on these exceedances, uncertainty is associated with using New Cranberry Pond as an un-impacted reference station. Nonetheless, the New Cranberry Pond sediment contaminant concentrations are far below those of Plow Shop Pond, and the macroinvertebrate study was conducted with New Cranberry Pond as a reference pond. New Cranberry Pond was also used as a reference pond for comparison to Cold Spring Brook Pond. A summary of the sediment chemistry at macroinvertebrate sampling stations in Cold Spring Brook Pond and New Cranberry Pond can be found in Table 7-27, and Subsection 7.2.3.2.

Surface water samples collected from Plow Shop Pond were analyzed for general water quality parameters, and the data were compared to those obtained from New Cranberry Pond. This purpose of this comparison was to determine if any of these parameters could have contributed to or influenced the results of the macroinvertebrate community evaluation. In general, water quality parameter data from stations at Plow Shop Pond differ little from those at New Cranberry Pond. The pH at both ponds was fairly close to neutral, ranging from 7.32 to 7.66 at Plow Shop Pond and 6.5 to 6.69 at New Cranberry Pond (Table 7-5). The pH readings at both ponds were between pH 6.5 to 9, the range where unacceptable effects to aquatic organisms should not occur. (USEPA, 1986).

Conductivity measurements obtained from the two ponds were markedly different, ranging from 179 to 195 microsiemens at Plow Shop Pond versus 43.6 to 49.6 microsiemens at New Cranberry Pond (Table 7-5). This suggests a higher

concentration of dissolved salts or suspended solids in Plow Shop Pond, which may be reflective of differences in surface water quality. Dissolved oxygen (DO) at Plow Shop Pond ranged from 4.4 to 8.3 ppm and DO at New Cranberry Pond ranged from 5.8 to 5.9 ppm. The Plow Shop Pond temperature was roughly 3°C higher than the temperature at New Cranberry Pond (17° versus 14°C).

General water quality parameters within each pond were evaluated to identify potential differences or trends associated with proximity to the landfill source. The parameters measured at the three stations within Plow Shop Pond did not vary greatly, with the exception of DO, which was lower at Station 1 (4.4 ppm) than at Stations 2 and 3 (7.3 ppm and 8.3 ppm, respectively). Station 1 is the station furthest from Shepley's Hill Landfill, and therefore this difference, if significant, does not appear to be attributable to the landfill.

Eutrophic New England ponds exhibit a wide variety of pH, temperature, and DO conditions across spatial and temporal gradients, and resident organisms must be able to tolerate these diverse conditions. The general water quality parameters do not appear to be influencing factors in the differences observed between the macroinvertebrate communities at the two ponds or at the different stations within a pond.

A checklist of Fort Devens macroinvertebrates collected as part of this study is found in Table 7-11. Macroinvertebrates were generally identified to the genus level. Macroinvertebrate communities are characterized by considerable spatial and temporal diversity. Therefore, the taxa listed in Table 7-11 represent the assemblage that was collected during the sampling effort, and are not representative of or intended to be used as a true checklist for Plow Shop Pond or any other aquatic resources at Fort Devens. Similarly, a checklist of Grove Pond macroinvertebrates is included as Table 7-12. This Grove Pond list represents organisms collected by MADEP during a one-time sampling event in September 1992 (see Section 2.0, Data Gap Activities). The Grove Pond macroinvertebrate data have not been further evaluated in this supplemental risk assessment.

Statistical evaluation of the Fort Devens macroinvertebrate data included the following techniques:

- Kruskal-Wallis tests of variance
- Analyses of Variance (ANOVAs) with Tukey's Studentized Range

- Clustering analyses
- Rapid Bioassessment Protocol (RBP) metric comparison
- Taxonomic similarity testing with Jaccard Coefficients of Community Similarity
- Simple linear regression
- Multiple linear regression

These analyses focused on comparisons between taxa and their abundances either directly, or through the use of species richness, biotic composition, and trophic richness metrics. A detailed presentation of the Fort Devens macroinvertebrate statistical community analysis is presented in Appendix P.

The following metrics were calculated for the phytomacrofauna and benthic substrate samples: taxa richness, modified family biotic index (FBI), ratio of Ephemeroptera, Plecoptera, and Trichoptera to Chironomidae (EPT/C) abundances, percentage contribution of the dominant family, and the EPT index (Tables P-1a, P-2a, P-3a and P-1b, P-2b, P-3b). In addition, a Jaccard Coefficient of similarity (Table P-6), statistical analysis of macroinvertebrate abundance (Tables P-7, P-8, and P-9), and a cluster analysis were done on the data (Figure P-1). Finally, a percentage comparability ratio was calculated, as described in the USEPA RBP manual (Plafkin et al., 1989) (Tables P-4 and P-5).

The results of the five metrics indicated that Plow Shop Pond had a significantly lower taxa richness than the other two ponds. New Cranberry Pond, the reference site, had the highest taxa richness of the three ponds (Tables P-2a and P-2b). New Cranberry Pond also had a significantly lower FBI than the other two ponds in the phytomacrofauna samples. This analysis indicates that New Cranberry Pond may have more pollution-intolerant species than either Plow Shop Pond or Cold Spring Brook Pond. Plow Shop Pond had a significantly higher percentage of pollution-tolerant dominant taxa in the vegetated substrate, and Cold Spring Brook Pond showed a similar result for the non-vegetated (i.e., benthic) substrates, indicating that the benthic community in both Plow Shop Pond and Cold Spring Brook Pond may be slightly impaired relative to that of New Cranberry Pond.

The RBP-III percentage comparability analysis indicated that Plow Shop Pond may have a slightly impaired macroinvertebrate community structure relative to New Cranberry Pond (Table P-4). Cold Spring Brook Pond was non-impaired

according to this analysis; however, other tests indicated that the macroinvertebrate community in Cold Spring Brook Pond may also be slightly impaired relative to that of New Cranberry Pond.

The Jaccard Coefficients indicated that the macroinvertebrate communities at the stations sampled closest to either landfill were most similar to each other (Table P-6). Stations farthest from the landfills at both sites had greater macroinvertebrate biodiversity, and were also similar to one another. Statistics done on the abundance of macroinvertebrates showed a similar result: the macroinvertebrate community in Plow Shop Pond appears to be slightly impaired, and the stations nearest to the landfills in both Plow Shop Pond and Cold Spring Brook Pond had reduced macroinvertebrate abundance (Table P-8). Analysis of macroinvertebrate abundance of different orders among ponds showed significant reductions in the Diptera and Cladocera at Plow Shop Pond (Table P-9). There were also more orders of macroinvertebrates not represented in collections at Plow Shop Pond than from Cold Spring Brook Pond and New Cranberry Pond.

The results of the cluster analysis were in accordance with the preceding analyses. This analysis indicated that the closer a station within a pond is to a landfill, the greater the impact to the macroinvertebrate community (Figure P-1). Similar effects were observed in Plow Shop Pond and Cold Spring Brook Pond, with reductions in both the number of taxa and the abundance of individuals within the taxa.

An analysis of the relationships between sediment chemistry and macroinvertebrate abundance, as well as diversity metrics, was inconclusive (Tables P-10 through P-17). This analysis suggested that no relationship exists between levels of the organic pesticides DDD, DDE, and DDT and differences in macroinvertebrate abundance and diversity in the study ponds. In addition, the sediment chemistry analysis indicated that no single inorganic COPC seems to be affecting the macroinvertebrate communities at the Group 1A sites. However, the statistical analysis did indicate that a group of approximately fifteen inorganic analytes may collectively impact the macroinvertebrates community. These include a combination of landfill and non-landfill related analytes, including arsenic, barium, beryllium, cadmium, copper, chromium, iron, mercury, manganese, nickel, antimony, and zinc. The statistical analysis suggested that arsenic, cobalt, iron, manganese, and mercury may be the five inorganic COPCs of

primary concern, relative to macroinvertebrate community abundance and diversity.

In summary, the statistical analyses indicate that Plow Shop Pond's macroinvertebrate community may be slightly impaired relative to that of New Cranberry Pond. The Plow Shop Pond macroinvertebrate community may be more impaired than that of Cold Spring Brook Pond, which may also be somewhat disturbed relative to New Cranberry Pond. Moreover, the data suggest that the macroinvertebrate stations closest to either landfill may be more impacted relative to those stations furthest from the landfills.

Considerable uncertainty is associated with the macroinvertebrate study at Fort Devens. This uncertainty is discussed in Subsection 7.3.

7.1.3.3 Ecological Exposure Assessment. The purpose of the supplemental ERA ecological exposure assessment is to evaluate the potential for ecological receptor exposure to chemical constituents in fish tissue, surface water, and sediments at the Shepley's Hill Landfill site. Ecological exposures to other environmental media have been previously evaluated in the original RI (E&E, 1993). This supplemental risk evaluation involves the identification of actual or potential exposure routes to receptors in Plow Shop Pond and evaluation of the magnitude of exposure to identified ecological receptors. In the exposure assessment, exposure concentrations are estimated for each receptor and for each exposure pathway evaluated in the supplemental risk assessment. This exposure information is used in conjunction with the toxicological information presented in the ecological effects assessment to evaluate ecological risk.

Exposure pathways describe the mechanism(s) by which ecological receptors are exposed to contaminated media, and consist of a(n): (1) contaminant source; (2) environmental transport medium; (3) point of receptor contact; and (4) the exposure route (e.g., ingestion of prey items that have bioaccumulated contaminants in their tissues, drinking of contaminated surface water, incidental soil ingestion, dermal absorption, and inhalation). A general overview of the exposure pathways considered in the Shepley's Hill Landfill supplemental risk assessment is presented in Table 7-13.

Potential receptors for which exposure and risks have been quantified include:

- Aquatic biota in Plow Shop Pond

- Semi-aquatic biota that depend on the aquatic environment for a portion of their life history requirements (i.e., wetlands wildlife)

Exposure to aquatic receptors from surface water and sediment have been evaluated via direct comparison of state and federal criteria and guidance values to concentrations of analytes detected in Plow Shop Pond surface water and sediments. Exposure to semi-aquatic ecological receptors has been evaluated using food web models. Evaluation of groundwater risks has previously been considered in the RI risk assessment (E&E, 1993).

Aquatic Biota. Aquatic fauna (including invertebrates, fish, reptiles, and amphibians) may potentially be exposed to contaminants through dermal contact with and ingestion of contaminated surface water and sediments. Exposures of aquatic fauna to sediments may occur via contact with and ingestion of contaminated sediment particles and interstitial pore water. Bioconcentration and bioaccumulation may provide significant exposure pathways for consumers of aquatic organisms. Bioconcentration is defined as "the process by which there is a net accumulation of a chemical directly from water into aquatic organisms resulting from simultaneous uptake (e.g., by gill and epithelial tissue) and elimination," whereas bioaccumulation is "a process by which chemicals are taken up by aquatic organisms from water directly or through consumption of food containing the chemicals" (Rand and Petrocelli, 1985). Bioaccumulation and bioconcentration from contaminated media potentially results in aquatic food chain effects, and could result in exposure to herbivorous, omnivorous, and carnivorous aquatic ecological receptors. Wetland plants may be exposed to contamination via direct contact with surface water, direct contact with surface water and direct contact, and root uptake from sediments and pore water.

To evaluate ecological risks to aquatic receptors, the exposure point concentrations employed in this supplemental risk assessment are the maximum and average concentrations of landfill COPCs (and non-landfill COPCs) in surface water and sediment.

Semi-aquatic Biota. Semi-aquatic fauna (including invertebrates, amphibians, reptiles, birds, and mammals) may be exposed to contamination via dermal contact with contaminated surface water and sediment, direct ingestion of surface

water and sediment, and by feeding on contaminated prey items. Bioconcentration and bioaccumulation from contaminated media potentially results in semi-aquatic food chain exposures, and could result in effects to semi-aquatic ecological receptors.

Semi-aquatic receptor's exposure via dermal uptake and inhalation have not been assessed in this supplemental risk assessment because little data regarding these exposure routes are available. Dermal exposure may be an ecologically significant exposure pathway for amphibians and for young, hairless mammals in subterranean dens (i.e., juvenile muskrats); however, in general, fur, feathers, and chitinous integument will minimize dermal absorption for most ecological receptors. In addition, because the primary COPCs at the Group 1A sites are inorganics, significant ecological exposure via the inhalation and dermal exposure pathways is not expected since metals (with the possible exception of mercury) tend to be poorly absorbed through the skin and tend not be volatilize. Inhalation exposures by ecological receptors are generally insignificant, except in emergency situations (e.g., following a chemical spill), and were not evaluated in this risk assessment.

Exposures to semi-aquatic receptors via ingestion of, and dermal contact with analytes in surface water were not evaluated. Some semi-aquatic species, however, have an aquatic life stage during which exposures to surface water is likely. Risks to these species are likely to be similar to those estimated for other aquatic life because USEPA's AWQC, which were used to estimate the risk, to aquatic receptors, incorporate available toxicity data for aquatic stages of amphibian species.

To evaluate food chain exposure to semi-aquatic ecological receptors at Plow Shop Pond, a simple food web model was employed to estimate the potential dietary exposure levels of analytes detected in sediments. Several potential receptor species representing various trophic levels within the ecological community in the vicinity of the Shepley's Hill Landfill were evaluated with the food web model.

The semi-aquatic ecological receptor species evaluated in the food web model were chosen because: (1) they may be potential ecological receptors at Fort Devens; (2) their various feeding habits (e.g., omnivorous, carnivorous) are representative of a typical southeastern New England semi-aquatic ecological

community; (3) most of these species were evaluated in the RI risk assessment (E&E, 1993); and (4) several of these species have previously been recommended for evaluation of ecological risks by USEPA and USFWS. Each species evaluated is assumed to be representative of other species within a trophic level at Fort Devens (i.e., a trophic guilding approach has been employed in this risk assessment).

The following indicator species were selected to represent exposure to semi-aquatic organisms via ingestion of food and sediment from Plow Shop Pond. These organisms rely on wetlands to fulfill many of their life history habitat requirements.

- Eastern Painted Turtle (*Chrysemys picta*). This widespread turtle is found in slow-moving shallow streams, rivers, and lakes. It prefers vegetated aquatic systems with soft bottoms and logs and rocks for basking. The eastern painted turtle hibernates by burrowing into soft mud or decaying vegetation in pond bottoms. Preferred food items for this omnivorous reptile include aquatic insects, snails, small fish, tadpoles, and aquatic vegetation (DeGraaf and Rudis, 1983). The eastern painted turtle has been used to represent the primary and secondary consumer reptilian community in the Fort Devens food web model.

- Green Frog (*Rana clamitans*). The green frog occurs throughout eastern North America. It is typically found in shallow waters in swamps, brooks, and the edges of ponds and lakes. Green frogs forage in shoreline vegetation, and prefer small fish and invertebrates, including insects, mollusks, and crustaceans. Green frogs in New England typically hibernate underwater or in soft muddy wetland bottoms, although they may be active on warm winter days (Degraaf and Rudis, 1983). The green frog has been used to represent the amphibian community in the Fort Devens food web model.

- Mallard Duck (*Anas platyrhynchos*). This widely distributed duck is found throughout temperate regions of the world and is the most abundant duck species throughout much of the northern hemisphere. Mallards prefer to feed on seeds of grasses, sedges,

and other graminoid plants; they will feed on submerged aquatic vegetation, including leaves, stems, and seeds. Mallard ducks will also feed on snails and insects (DeGraaf and Rudis, 1983; Terres, 1987). The mallard has been used to represent the primary and secondary consumer avian community in the food web model.

- Great Blue Heron (*Ardea herodias*). This widely distributed bird is the largest North American heron, standing up to four feet tall and weighing five to eight pounds (Terres, 1987). Although it is a migratory species, the great blue heron winters over much of its breeding range and may occur year-round in southern New England, especially during milder winters. Great blue herons are frequently observed in the shallows of ponds, lakes, streams, rivers, wet meadows, marshes, and forested swamps (DeGraaf and Rudis, 1983). A colonial nester, this species prefers tall trees and snags in forested swamps (Terres, 1987). Major prey items of the great blue heron include aquatic insects, amphibians, reptiles, crustaceans, and occasionally small birds and mammals. The great blue heron has been used to represent the secondary and tertiary consumer avian community in the food web model.

- Osprey (*Pandion haliaetus*). This piscivorous bird of prey occurs along lakes, rivers, and coastal areas in both the northern and southern hemispheres. Osprey spend much of their time perched on dead tree snags or rocks along the water's edge. Osprey typically hover at heights of 30 to 100 feet above the water surface; when a fish is spotted, osprey will plunge into the water and capture it in both talons (Terres, 1987). Osprey nest on the tops of a variety of natural and man-made objects, including trees and artificial nesting platforms. In Massachusetts, the osprey was a state-protected species until 1990, when it was removed from the list of endangered species (Dumanoski, 1990). The bird only nests in coastal counties in Massachusetts, from the Rhode Island border to Essex County. However, during fall and spring migration, birds are known to stop at Fort Devens and fish in the installation's aquatic systems. The osprey has been used to represent the tertiary consumer avian community in the food web model.

- Muskrat (*Ondatra zibethicus*). This common mammal is widespread throughout North America (Burt and Grossenheider, 1976). Its preferred habitat includes marshes, portions of lakes, ponds, swamps, sluggish streams, and drainage ditches; it is most abundant in regions with cattails (*Typha* sp.) (Degraaf and Rudis, 1983). Muskrats feed on a variety of aquatic and emergent plant species, including cattails, common reed (*Phragmites australis*), bulrushes (*Scirpus* sp.), and a variety of grasses; this rodent will also occasionally feed on mollusks, crayfish, frogs, and fish (DeGraaf and Rudis, 1983; Baker, 1983; Burt and Grossenheider, 1976). Muskrats spend much of their time in tunnels, lodges, burrows, and feeding shelters (Baker, 1983). Populations of this species may undergo annual and multi-annual fluctuations (DeGraaf and Rudis, 1983). The muskrat has been used to represent the primary and secondary consumer small mammal community in the food web model.

- Raccoon (*Procyon lotor*). The raccoon is a medium-sized mammal that occurs throughout much of North America. Raccoons inhabit woodlands, agricultural fields, and wetlands; frequently they are found in areas of human habitation. Raccoon dens include a variety of protected areas, ranging from culverts to hollow logs and abandoned woodchuck burrows. Opportunistic and omnivorous, the raccoon prefers to feed on animal prey items including crawfish, worms, and insects, as well as fruits, seeds, vegetation, and garbage. This mammal is has been used to represent the omnivorous mammal community in the food web model.

- Mink (*Mustela vison*). This semi-aquatic predator is a member of the weasel family. It prefers stream banks, forested wetlands, marshes, and secondary growth uplands (DeGraaf and Rudis, 1983; Baker, 1983). Mink populations may be highest in large wetlands containing cattails and muskrats, where populations of nine to 15 animals per square mile can be expected (Baker, 1983). Minks feed on a variety of aquatic and aquatic prey items, including small mammals (such as muskrats), fish, frogs, salamanders, crayfish, mollusks, and insects (DeGraaf and Rudis, 1983; Baker, 1983). This carnivorous mammal is active year-round, and has been used to

represent the secondary and tertiary consumer mammal community in the food web model.

These eight species were selected because they are representative of the range of mammals, birds, reptiles, and amphibians that may occur in the vicinity of the Shepley's Hill Landfill at Fort Devens. The eastern painted turtle, green frog, mallard duck, raccoon, and great blue heron are all common breeding animals at Fort Devens. These species have been observed at Plow Shop Pond and Cold Spring Brook Pond. Although mink and muskrat have not been observed at either pond by ABB-ES, these two species are common breeding animals at Fort Devens and are known to occur in the vicinity of both of the Group 1A sites. Osprey do not breed at inland sites in New England; however, they are annually observed in Worcester County during spring and fall migration. A few visual records for osprey over Plow Shop Pond exist. Exposure parameters for these species are presented in Table Q-1, in Appendix Q.

Recent studies have indicated that the magnitude of fish tissue contaminant burden may not be directly related to the magnitude of sediment contamination (Weiner, 1993). It is likely that other factors, including fish lipid content, trophic level of the fish evaluated, and trophic status of the aquatic resource evaluated, may explain ecological partitioning of analytes in aquatic systems (Rowen and Rasmussen, 1992). Nonetheless, for the purpose of modeling ecological exposure to analytes detected at Plow Shop Pond, bioaccumulation factors (BAFs) that model direct uptake from sediments were assumed to play a major role in trophic transfer processes.

To model food chain exposure to COPCs in sediment and fish tissue, estimated tissue residues in prey items were calculated using BAFs. When empirical data were available from the fish tissue study, BAFs for fish were calculated by dividing the average (arithmetic mean) fish tissue concentration by the average (arithmetic mean) sediment concentration. Analyte-specific fish BAFs were established by dividing the average fish tissue concentration by the average sediment concentration in each pond. Therefore, multiplying the fish BAF by the average sediment concentration for a particular analyte results in the detected average fish concentration. Rather than calculate a second BAF for the RME evaluation, the established fish BAF was multiplied by the maximum sediment concentration to establish the RME exposure point concentration. The RME evaluation, therefore, considered the maximum sediment concentration on an

analyte-by-analyte basis, as well as a fish tissue exposure point concentration well above the average fish tissue level. This value represents in realistic RME exposure point for the pond. An assumption has been made that the other vertebrate taxa evaluated in the food web model accumulate sediment contaminants to the same degree as the fish. Consequently, the BAFs derived from the fish tissue data were used to model uptake by other classes of vertebrate receptors.

Several analytes were undetected in fish tissue, but were found in Plow Shop Pond sediments; conversely, several other analytes were detected in fish tissue, but were undetected in sediments. In these cases, a value of one-half the fish tissue or sediment SQL was used to conservatively estimate the BAF. When literature values were available for organisms other than fish (e.g., plants and invertebrates), these literature values were used to generate BAFs. When literature values were not available, conservative assumptions and extrapolation techniques were used to estimate BAFs. BAFs used in the supplemental risk assessment are presented in Table Q-2, in Appendix Q.

Estimated analyte tissue residues in prey species were estimated by multiplying either the average (for the average exposure scenario) or the maximum (for the RME scenario) sediment analyte concentrations by chemical-specific BAFs, as shown in the following equation:

$$\textit{Prey Tissue Concentration } (mg/kg) = \textit{Sediment Concentration } (mg/kg) \times \textit{Bioaccumulation Factor } (BAF)$$

To estimate dietary exposure concentrations for the modeled receptors under the average exposure scenario, the potential food chain exposure point concentration in fish tissue is therefore the average COPC concentration detected in Plow Shop Pond fish. For the RME scenario, a conservative assumption has been made that the fish tissue exposure point concentration is greater than the average COPC concentrations detected in fish tissue.

The Potential Exposure Dose (PED) level associated with ingestion of contaminated prey items for each modeled receptor species was calculated by

multiplying each predicted prey species tissue concentration by the proportion of that prey type in the diet, summing these values, multiplying by the receptor species' Site Foraging Frequency (SFF), Exposure Duration (ED), and Ingestion Rate (IR), and dividing by the receptor species' body weight (BW). The PED_{diet} is represented by the following equation:

$$PED_{diet} = [P_1 \times T_1 + P_2 \times T_2 + \ldots P_n \times T_n] \times SFF \times ED \times IR/BW$$

w
here:

PED_{diet}	=	Potential Exposure Dose (mg/kgBW-day)
P_n	=	Percentage of diet represented by prey item ingestion
T_n	=	Tissue concentration in prey item (mg/kg); calculated by multiplying the analyte concentration in sediment (or food item) by a bioaccumulation factor
SFF	=	Site Foraging Frequency; Area of Contaminated Sediment (acres)/Home range (acres)
ED	=	Exposure Duration (unitless)
IR	=	Ingestion Rate (kg/day)
BW	=	Body Weight (kg)

Potential exposure dosages for the incidental sediment ingestion pathway ($PED_{sediment}$) (i.e., associated with foraging, preening, and cleaning activities) were estimated by multiplying the sediment concentrations by the estimated percentage of sediment in the diet of each modeled receptor species, multiplying by the SFF, ED, and ingestion rate, and dividing by BW. For the receptors evaluated at Shepley's Hill Landfill, incidental sediment ingestion was conservatively assumed to range from 0 to 5 percent of the receptor's dietary intake, based in part on a recent presentation of Beyer and Connor (1992). The area of contaminated pond was assumed to be 30 acres (the entire pond) for the purpose of calculating the SFF.

Exposure dosages associated with these two pathways were summed to calculate a Total Body Dose (TBD):

$$TBD = PED_{diet} + PED_{sediment}$$

where:

TBD	=	Total Body Dose (mg/kgBW-day)
PED_{diet}	=	Potential Dietary Exposure Dosage (mg/kgBW-day)
$PED_{sediment}$	=	Potential Sediment Exposure Dosage (mg/kgBW-day)

TBD estimates, expressed in mg/kgBW-day, are directly comparable to the available toxicological dose-response data and were used in conjunction with toxicological data to evaluate ecological risks to semi-aquatic receptors at the Shepley's Hill Landfill.

7.1.3.4 Ecological Effects Assessment. The purpose of the Ecological Effects Assessment is to select the ecological characteristics (endpoints) to be evaluated, describe the environmental risks associated with the identified COPCs in each medium of concern, and to evaluate the relationship between the concentration to which an organism is exposed and the potential for adverse effects. The toxicological evaluation includes the process of characterizing the inherent toxicity of the COPCs and establishing reference or threshold toxicity values for each identified analyte. Information contained in the ecological effects assessment, in conjunction with exposure information presented in the previous subsection, is used to evaluate ecological risks to aquatic and semi-aquatic organisms in the ecological risk characterization.

This subsection addresses the potential effects of COPCs in Plow Shop Pond surface water, sediments, and fish tissue. Ecological effects associated with exposure to other environmental media have previously been evaluated in the original RI (E&E, 1993). In addition, relevant aspects of the data gap ecological field program, as presented in Section 2.0, are discussed in the context of providing corroborative evidence between contaminant exposures and ecological effects.

Selection of Endpoints. The first component of the Ecological Effects Assessment consists of identifying ecological characteristics or endpoints that may be adversely affected by exposure to an environmental stressor (for instance, a COPC). Two types of ecological endpoints were considered: assessment endpoints and measurement endpoints (Suter, 1993; USEPA, 1992c). Assessment endpoints formally describe the environmental value(s) to be protected. The definition of assessment endpoints is a critical component of the ecological effects assessment and consists of identifying the environmental attributes potentially at risk (Suter, 1993). In most cases, the assessment endpoint cannot be directly measured, and a measurement endpoint (or suite of measurement endpoints) has been selected that can be related, either qualitatively or quantitatively, to the assessment endpoint (USEPA, 1992c).

Assessment and measurement endpoints can be evaluated at individual, population, community, or ecosystem levels. In general, assessment endpoints selected for the Shepley's Hill Landfill supplemental risk assessment are related to the presence, abundance, and diversity of ecological receptor species. These endpoints were selected because it was assumed that site contamination may result in certain species avoiding contaminated habitats (resulting in relative scarcity or absence of intolerant receptors) or suffering toxic effects from exposure to contaminants (Maughan, 1993).

Because long-term monitoring data concerning population levels of the ecological receptors at the Group 1A sites are not available and are impractical to collect, these assessment endpoints were not directly evaluated. Rather, the assessment endpoints were evaluated through extrapolation from measurement endpoints, which were generally the observed, estimated, or predicted effects of COPCs on survival, growth, and reproduction of individual organisms. In addition, limited measurement endpoint data are available from the qualitative fish population study and the semi-quantitative macroinvertebrate community study.

To establish endpoints for evaluation of COPC effects, measurement endpoints were generally used to model assessment endpoints. Toxicological or protective benchmark values that relate the magnitude of expected effects to a given level of exposure to the COPCs were selected for each environmental medium. From the toxicological data set evaluated, chronic toxicity values for each representative species or medium were selected as the benchmark Reference Toxicity Values (RTVs) for each COPC. These benchmark RTVs, representing a threshold

concentration or dose for effects to aquatic and semi-aquatic organisms, are expressed in $\mu g/L$ in surface water, $\mu g/g$ in sediments, and the mass of constituent per unit body weight per day for semi-aquatic organisms (mg/kg BW [body weight]/day). Relevant toxicity information on the landfill-related COPCs can be found in Section 7.3.4.1 of the original RI risk assessment (E&E, 1993).

Toxicity to Aquatic Receptors. Limited data are available to evaluate the potential for toxic effects of analytes detected in Plow Shop Pond surface water and sediments on aquatic life. Available information includes federal water quality criteria, state and federal sediment quality criteria and guidance values, laboratory-derived toxicity data, and toxicity threshold values developed using toxicological extrapolation techniques. The risks to aquatic receptors from Plow Shop Pond surface water and sediment contamination have been evaluated through comparison of concentrations of analytes present in surface water and sediment to the benchmark concentration RTVs for these media. A discussion of available criteria or other values used to derive benchmark RTVs for surface water is presented below, followed by a discussion of available criteria or guidance values used to derive benchmark RTVs for sediment.

Surface Water Benchmark RTVs

- **USEPA Ambient Water Quality Criteria.** Ambient Water Quality Criteria (AWQC) have been developed and published by the USEPA for the protection of aquatic life and its uses (USEPA 1983b). Both acute and chronic AWQC have been developed for many of the analytes detected in surface water at Fort Devens. Acute AWQC are defined as one-hour average concentrations not to be exceeded more than once every three years, and chronic AWQC are defined as four-day average concentrations not to be exceeded more than once every three years. AWQC values are based on biological effects studies on aquatic organisms such as algae, cladocerans, fish, and amphibians reporting effects such as lethality or impaired growth or reproduction. Commonly reported values include median lethal concentration (LC_{50}) studies, which represent the lowest single concentration which is lethal to 50 percent of the study population, and Lowest Observable Effect Concentration (LOEC), which represent the lowest concentration at which adverse effects were observed in the study population.

Methods used to derive the AWQC are presented in "Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic organism and their uses" (USEPA 1983b). Criteria for several inorganics are dependent upon water hardness, with toxicity increasing as hardness decreases. Therefore, a site-specific water hardness of 35.1 mg/L was used to calculate the AWQC.

- **Other Aquatic Toxicity Data.** USEPA AWQC are not available for some Fort Devens COPCs. In cases where no AWQC were available, scientific literature was reviewed and values from relevant toxicity studies were selected as RTVs. RTVs for these COPCs were derived from the literature by compiling available acute and chronic toxicity values. In cases where only a very limited number of values were available, the lowest value was selected. If this value was for a severe response (e.g., lethality) a safety factor of 0.2 was applied to derive the acute RTV. If no chronic values were available, a factor of 0.1 was applied to the acute RTV to derive a chronic RTV. This factor is based on observations by Newell et al., (1987) that acute and chronic toxicity values often differ by roughly one order of magnitude.

A summary of surface water RTVs is presented in Table 7-14.

Sediment Benchmark RTVs

- **USEPA Interim Sediment Quality Criteria.** Interim sediment quality criteria for several hydrophobic organic compounds have been developed and published by the USEPA (1988). Although referred as criteria, the values contained in this document are intended to be used as guidance, rather than as numerical criteria. No USEPA interim sediment quality criteria are available to evaluate the effects of inorganic constituents on aquatic life. However, the USEPA interim sediment quality criteria were used to evaluate the organic COPCs in Plow Shop Pond that did not originate in the landfill. The USEPA interim sediment quality criteria are intended to protect benthic organisms that are primarily impacted by contaminants in the interstitial water between sediment

particles. USEPA developed interim sediment quality criteria using an equilibrium partitioning approach to identify sediment concentrations that could be associated with interstitial water concentrations equal to chronic federal AWQC.

For non-polar, hydrophobic organic compounds, such as PCBs, the degree to which compounds are released from sediment particles into the interstitial water is strongly influenced by their low solubility and strong binding affinity to TOC within the sediment particle. The higher the carbon content of the sediments, the lower the potential for contaminant release to the interstitial water. Therefore, the toxicity of sediments containing hydrophobic compounds (and subsequently the associated sediment toxicity criteria) varies on a site-specific basis in an inverse relationship with the fraction of sediment that is organic carbon. For this reason, when appropriate, Fort Devens sediment toxicity threshold criteria were carbon-normalized. Carbon-normalized interim criteria were calculated by multiplying the average carbon content of the sediments by the appropriate sediment quality criteria. Ecological risk was evaluated through direct comparison of this carbon-normalized interim value with the sediment analytical data.

Considerable uncertainty is associated with use of the USEPA interim sediment quality criteria for the pesticide DDT. It is possible that the DDT interim sediment quality criteria is approximately an order of magnitude lower than is necessary to protect aquatic life at Fort Devens. A discussion of the uncertainty associated with use of this value can be found in Appendix S.

- **National Oceanographic and Atmospheric Administration (NOAA) Sediment Threshold Values.** Long and Morgan (1990) have developed biological effects-based criteria for evaluating sediment contaminant data. Although this NOAA study is designed primarily for evaluating the toxicity of marine and estuarine sediments, USEPA Region I has suggested at other Fort Devens study areas that Long and Morgan (1990) criteria may also be used as a source of information for the evaluation of freshwater sediments at hazardous waste sites. Furthermore, these NOAA guidelines are

frequently used as an ecological risk assessment screening tool in USEPA Region I. The Effects Range-Medium (ER-M) of Long and Morgan (1990) represents the 50th percentile concentration of contamination in estuarine sediments with observed (or predicted) effects. The Effects Range-Low (ER-L) of Long and Morgan (1990) represents the 10th percentile concentration of contamination in estuarine sediments with observed (or predicted) effects. When USEPA sediment quality criteria were not available, the NOAA ER-L was used to evaluate Plow Shop Pond sediment contamination.

- **New York State Department of Environmental Conservation (NYSDEC) Sediment Quality Criteria**. The NYSDEC Bureau of Environmental Protection, Division of Fish and Wildlife of NYSDEC has published a document entitled "Sediment Criteria - December 1989" (NYSDEC, 1989). This report is a guidance document, not a NYSDEC standard or policy. The NYSDEC sediment quality criteria document contains a methodology for developing sediment criteria, a description of the use of these criteria in risk management decision-making processes, and a table of sediment criteria derived for various human and ecological receptors. Organic contaminant sediment criteria developed in NYSDEC (1989) are based on the equilibrium partitioning approach. The NYSDEC (1989) guidance document contains recommended criteria for several organic and inorganic constituents found in Fort Devens sediments. When neither USEPA sediment quality criteria nor NOAA ER-L values were available, NYSDEC values were used to assess aquatic toxicity at Plow Shop Pond. Organic NYSDEC values were carbon-normalized.

A summary of sediment benchmark concentration RTVs is presented in Table 7-15. Several additional sediment quality criteria and guideline values are also included in Table 7-15.

Toxicity to Semi-aquatic Receptors. Potential impacts to semi-aquatic ecological receptors at estimated exposure concentrations were evaluated using published laboratory-derived toxicological data, as well as threshold toxicity values developed using extrapolation techniques. Toxicological endpoints evaluated

included behavioral effects, developmental effects, physiological changes, and changes in organ weight, size, or functionality. Lethal dose studies (e.g., LD_{50} studies) and effects studies (e.g., EC_{50} studies) were considered.

Oral ingestion studies were preferentially chosen as measurement endpoints in the following order: (1) feeding studies, (2) gavage studies, (3) drinking water studies. Based on these data, benchmark dosage RTVs were developed to represent a threshold dose for effects to organisms. Benchmark dosage RTVs are expressed in mg/kg BW (body weight)/day (dose normalized to body weight). From the toxicological data set evaluated (Appendix Q, Table Q-3), compound-specific chronic toxicity values for each type of receptor (indicator species) were selected as the Group 1A benchmark dosage RTVs. These benchmark dosage RTVs are presented in Appendix Q, Table Q-4.

The chronic benchmark dosage RTV selection procedure included the following general guidelines:

- Taxon-specific toxicological data were used whenever possible, regardless of study duration. When taxon-specific data were unavailable, available toxicological data were used as surrogate toxicological benchmarks for various indicator species. Because reptile and amphibian toxicological data are scarce, bird toxicity values were used to represent most green frog and painted turtle benchmark dosage RTVs.

- Chronic benchmark dosage RTVs were generally based on the average of reported Lowest Observed Adverse Effect Levels (LOAELs) for non-mortality endpoints from chronic studies (i.e., those lasting more than 364 days). However, when chronic non-mortality data were unavailable, the average of reported LOAEL non-mortality data from sub-chronic studies (those lasting 15 to 364 days) were used for the benchmark dosage RTV. Mortality data from chronic studies were used only when data from chronic or sub-chronic non-mortality studies were unavailable. LOAELs extrapolated from acute or No Observable Adverse Effect Levels (NOAELs) were not included when LOAELs were averaged to derive benchmark dosage RTVs.

- When chronic or sub-chronic studies were not available, acute study values were used. In these cases, two factors are applied to the acute Lethal Dose Fifty (LD_{50}) (the single dose lethal to 50 percent of the test organisms). These include: (1) a factor of 0.2 for extrapolating from the oral LD_{50} to a value expected to protect 99.9 percent of the population from acute effects (USEPA, 1986); and (2) a factor of 0.1 for extrapolating from acute to chronic values (the acute-chronic ratio for many is approximately 10 (Newell et al., 1987)). Additionally, in cases where only a NOAEL value was available, a factor of 5 was used to extrapolate an estimated LOAEL from the NOAEL value. LOAELs extrapolated from chronic or sub-chronic NOAEL data were preferentially used over data extrapolated from acute studies.

- When no studies were available in the ABB-ES database for a given analyte, an appropriate surrogate with adequate toxicological data was assigned (e.g., DDT was used as a surrogate for DDD and DDE).

Field Observations. Limited measurement endpoint data are available from the qualitative fish population study and the semi-quantitative macroinvertebrate community study. The macroinvertebrate study has been summarized in Subsection 7.1.3.2 and in Appendix P. In addition, field observations of physically stressed vegetation were summarized in the original risk assessment (E&E, 1993).

Fish. As detailed in Sections 2.0 and Subsection 7.1.3.2, fish were collected from Plow Shop Pond to provide baseline information regarding the status of the fishery in the pond. Interactions between contaminants and fish populations are poorly understood, and no single pathological condition in individual fish or in fish populations serves as a universal contaminant stress indicator (Hunn, 1988). However, certain physical, anatomical, bio, and physiological conditions are known to be associated with environmental pollutants. These conditions include fin erosion, skin ulcerations, skeletal abnormalities, tumors, and scale disorientation (Hunn, 1988).

As part of the fish study, a number of individual fish were checked for external pathological gross abnormalities (e.g., tumors, lesions, structural or bone defects) through an evaluation of the conditions of the lips, jaws, barbels (when

applicable), eyes, right gill, fins, urogenital cavity, anus, body form, and body surfaces. All data were recorded on field data sheets.

The gross pathological examination of fish from Plow Shop Pond suggests that the individual fish evaluated were healthy (Table 7-16). No tumors or lesions were observed in any fish examined; barbels on all bullheads examined were uniformly intact and free from abnormalities. Of the 161 fish examined, eleven exhibited minor physical abnormalities. A slight fraying of fins was noted in five fish: this phenomenon is commonly observed in many non-stressed fish populations. Several other minor physical abnormalities observed on Plow Shop Pond fish may be the result of historical predation and injuries from human fishing hooks (e.g., a deformed jaw was observed on one pickerel).

7.1.3.5 Ecological Risk Characterization. This subsection characterizes the risk to aquatic and semi-aquatic receptors potentially exposed to COPCs in Plow Shop Pond surface water sediment, and fish tissue. Risks were quantitatively evaluated using HQs, which were calculated for each COPC by dividing the estimated exposure concentration or dose by the concentration or dosage benchmark RTV. In addition, relevant aspects of the Data Gap ecological field program, as presented in Section 2.0, are discussed relative to the ecological risk characterization.

RME and average exposure HQs for aquatic organisms were estimated by dividing the maximum and average environmental concentrations, respectively, of each COPC by the concentration RTV (typically a surface water or interim sediment quality criterion or guideline). To calculate RME HQs for the semi-aquatic organisms evaluated through food web modeling, the dose based on the maximum concentration of each COPC was divided by the dosage RTV. Average exposure HQs were calculated by dividing the dose based on the average COPC concentrations by the appropriate dosage RTV. Summary HIs were determined by summing the HQs for all COPCs.

When the estimated exposure point concentration or dose was less than the benchmark RTV (i.e., the HQ < 1), ecological risk has been assumed to be insignificant. When the estimated dose or exposure point concentration exceeded the benchmark RTV (i.e., HQ > 1), a discussion of the ecological significance of this exceedance has been included. This hazard ranking scheme evaluates potential ecological effects to individual organisms, and does not evaluate

potential population-wide risks. Contaminants may cause population reductions by affecting birth and mortality rates, immigration and emigration (USEPA, 1989a). In many circumstances, acute (or chronic) effects may occur to individual organisms with little potential population or community level impacts; however, as the number of individual organisms experiencing toxic effects increases, the probability that population effects will occur also increases. The number of affected individuals in a population presumably increases with increasing HQ or HI values; therefore, the likelihood of population level effects occurring is generally expected to increase with higher HQ or HI values.

Risk to Aquatic Receptors from Surface Water. Comparison of the Plow Shop Pond surface water COPC concentrations with RTVs provides a means to evaluate the potential for adverse effects to aquatic environmental receptors from exposure to COPCs (Table 7-17). This comparison indicates that aquatic life could potentially be at risk from exposure to contaminated surface water in Plow Shop Pond.

Average exposure point concentrations were compared with chronic AWQC to provide an indication of risks associated with average exposure conditions. RME (maximum detected) exposure point concentrations were compared with acute AWQC to provide an indication of risk associated with RME conditions. Average and RME concentrations of both copper and silver (non-landfill related COPCs) exceeded the respective chronic and acute AWQC. Although silver was detected in only two out of 15 samples, the detection limit of 0.316 $\mu g/L$ reported for silver is higher than the chronic AWQC. It is therefore possible that the actual concentrations in the 13 non-detect samples, and the average concentrations were above the chronic AWQC. The RME concentration of zinc (also a non-landfill related COPC) was slightly higher than the acute AWQC. Given that only a small fraction of any aquatic population is likely to be exposed to a maximum concentration, adverse ecological impacts (i.e., adverse impacts at the population and community levels) from exposure to zinc are considered unlikely. It is important to note that the majority of AWQC incorporate considerable data from studies using sensitive cold water species, such as rainbow trout, which do not occur in the fish community in Plow Shop Pond. These criteria may therefore be over-protective of species such as bluegill sunfish which are generally less sensitive to environmental contaminants.

An uncertainty associated with the evaluation of the E&E (1993) surface water data is associated with the use of samples analyzed for total, rather than dissolved, contaminants. Recent USEPA national guidance recommends that dissolved contaminant data be used for ecological risk assessments evaluating surface water. Dissolved contaminant data better represent the bioavailable fraction of contaminants present in surface water. Therefore, the use of total contaminant surface water data (rather than the dissolved fraction) results in an over-estimate of risk from surface water at the Group 1A sites.

The surface water average and RME hazard indices are 7.7 and 12.8, respectively. Copper and silver are the primary contributors to this hazard index. These findings suggest that any potential risks to aquatic receptors at Plow Shop Pond may be primarily attributable to sources other than the Shepley's Hill Landfill, as assessed in this report.

Risks to Aquatic Receptors from Sediment. Comparison of the Plow Shop Pond sediment COPC concentrations with concentration RTVs provides a means to evaluate the potential for adverse effects to aquatic environmental receptors from exposure to COPCs (Table 7-18). This comparison indicates that aquatic life may be at risk from exposure to contaminated sediments in Plow Shop Pond.

Concentrations of all five landfill-related analytes (arsenic, barium, iron, manganese, and nickel), as assessed in this report, exceed the available sediment RTVs. The average exposure HQ for arsenic was 14.2, whereas the RME HQ for this analyte was 97. Average exposure and RME HQs for barium were 5.4 and 17.2, respectively, whereas the average and maximum HQs for manganese were 6.2 and 128. The average exposure nickel concentration did not exceed its RTV, and the RME HQ for nickel was 2.6. Average iron concentrations resulted in an HQ of 1.5, whereas the maximum iron concentration resulted in an RME HQ of 13.8.

Other non-landfill related COPCs in Plow Shop Pond sediments were also present in concentrations in excess of their RTVs. HQs for the majority of organic analytes were less than 1, with the exception of the RME HQ for DDE, and DDD which were 4.8 and 6.6 respectively. HQs from aquatic receptor exposure to average concentrations of cadmium, chromium, and mercury were 2, 24.8, 3.6 and 121 respectively. RME HQs ranged from a low of 1.1, for cobalt, to a high of

867, for mercury. The RME HQs for cadmium, chromium, copper, lead, and zinc were also greater than 1, and ranged from 1.9 (copper) to 125 (chromium).

Approximately 15 percent of the average exposure aquatic HI for Plow Shop Pond is attributable to landfill analytes in sediments: approximately one-half the risk from average concentrations of landfill analytes is attributable to arsenic. The remaining 85 percent of the average exposure HI is contributed by analytes originating from sources other than the Shepley's Hill Landfill, as assessed in this report (Figure 7-4). Over 65 percent of the risk to aquatic receptors, based on the average exposure HI, is due to mercury contamination. Similarly, less than 20 percent of the RME HI resulting from exposure by aquatic receptors to maximum concentrations of analytes is attributable to landfill analytes. Approximately one-half of the RME HI for landfill analytes is attributable to manganese; however, the manganese HQ is attributable to the manganese concentration detected in one sample (SHD-92-02 at 54,800 $\mu g/g$), which is an order of magnitude higher than manganese concentrations in any other sample. The remaining portion of the RME HI is due to exposure to analytes other than the five analytes that are attributable to the Shepley's Hill Landfill. Approximately two thirds of the risk to aquatic receptors, based on the RME HI, is due to mercury contamination.

These findings suggest that contaminants from sources other than the Shepley's Hill Landfill are major ecological risk contributors to aquatic receptors at Plow Shop Pond. However, exposures to landfill constituents are sufficient to result in predicted adverse effects to aquatic biota.

Risks to Semi-aquatic Receptors. Risks to semi-aquatic receptors at Shepley's Hill Landfill were evaluated through use of a food web exposure model. Analyte-specific TBDs for each model receptor species were calculated as described in Subsection 7.1.3.3, and provide an estimate of the combined effects of exposure to sediment and the consumption of contaminated prey items. The TBD for each constituent was compared to the dosage RTV to develop average exposure and RME HQs. For each species evaluated, HIs were determined by summing the HQs for all COPCs (Table 7-19). Estimates of exposure and risk to semi-aquatic receptors at the Shepley's Hill Landfill are presented in Appendix R, Tables R-1 through R-8.

Under average exposure conditions, hazard indices (HIs) exceeded 1 for five of the eight receptors evaluated, including the mallard (HI=1.4), green frog (HI = 3.5), painted turtle (HI = 2.8), muskrat (HI = 1.4), and mink (HI = 1.4). Primary risk contributors included the landfill analytes arsenic and manganese, as well as the non-landfill analytes (primarily lead, mercury, and chromium).

For the green frog, primary contributors to risk under average exposure conditions were chromium (HQ = 1.8) and arsenic (HQ = 1.2). The primary contributor to risk for painted turtle was chromium (HQ = 1.5), with arsenic also contributing (HQ = 0.82). None of the COPC specific HQs for the mallard, muskrat, and mink exceeded 1 under average exposure conditions. Primary contributors to risk for mallard were arsenic (HQ = 0.56) and chromium (HQ = 0.55). Primary contributors to risk under average exposure conditions for the muskrat were arsenic (HQ = 0.71) and selenium (HQ = 0.2), and those for mink were mercury (HQ = 0.71), manganese (HQ = 0.22), and selenium (HQ = 0.21).

Under RME exposure conditions, HIs exceeded 1 for the great blue heron (HI = 3.3), as well as for the five receptors mentioned above (mallard [HI = 8.4], green frog [HI = 21], painted turtle [HI = 16], muskrat [HI = 8.3], and mink [HI = 12). Primary risk contributors for these five species were similar to the average exposure scenario, with arsenic, chromium, and mercury being the primary risk contributors. Primary contributors to risk for the great blue heron were chromium (HQ = 1.4) and mercury (HQ = 1.1). HIs for the osprey and raccoon under both average and RME exposure conditions were below 1, indicating little potential for risk to these species from exposure to COPCs. This is due primarily to the large foraging area of the osprey and the diverse dietary composition of the raccoon.

For semi-aquatic wildlife with HIs greater than 1, the contribution of the five landfill analytes to the total RME and average exposure HIs ranged from approximately 20 percent (great blue heron) to approximately 65 percent (muskrat). The remainder of the summary HIs was due to COPCs from sources other than the Shepley's Hill Landfill (Figures 7-5 and 7-6), as assessed in this report. The three primary non-landfill COPC risk contributors are chromium, lead, and mercury.

These findings indicate that contaminants from both Shepley's Hill Landfill and other sources (as assessed in this report) are contributors to ecological risk for

semi-aquatic receptors at this site. Semi-aquatic species with a small home range and direct contact with sediment (e.g., the green frog or painted turtle) are likely to be most at risk from COPCs in Plow Shop Pond sediments.

Field Program Risk Characterization. Considerable uncertainty is associated with evaluation of several of the measurement endpoints in the fish and macroinvertebrate studies. Inherent environmental variability limits the use of measurement endpoints evaluated in the ecological field program. However, limited measurement data from the macroinvertebrate community study and the fish study are available to assist with risk characterization at the Shepley's Hill Landfill.

Fish Study. The fish community study was qualitative in nature and was not intended to provide an inventory or survey of all fish in Plow Shop Pond. However, as detailed in Subsection 7.1.3.2, the results of the qualitative fish community study suggest that the fish species composition and taxa richness of Plow Shop Pond is characteristic of typical southern New England ponds. A total of 193 individual fish representing seven families and 12 species were captured in the pond. Top predators, including the largemouth bass and chain pickerel, as well as various insectivorous and omnivorous were abundant in Plow Shop Pond. Several sizable largemouth bass (i.e., greater than 3.5 kg) were found in Plow Shop Pond; in addition, a possible young-of-the year bass was also found in the pond, indicating a reproductively viable population.

The gross pathological evaluation of the fish community also was not designed to quantitatively evaluate all sub-lethal indicators of contaminant stress. However, the results of this evaluation suggest that, in terms of gross external pathological indicators, the members of the fish population evaluated from Plow Shop Pond were healthy. A total of 161 fish from Plow Shop Pond were inspected for gross pathological abnormalities (i.e., tumors, lesions, structural, or bone defects). No tumors, lesions, ulcerations, skeletal anomalies or other gross pathological conditions associated with contaminant stress were found in any fish examined.

In general, the lower trophic level fish species evaluated (e.g., the bluegill) contained higher average concentrations of several inorganic analytes (e.g., iron and manganese) than did higher trophic level species. This may reflect the fact that these fish are omnivorous and are obtaining iron and manganese from plant food sources (Moore, 1991). Conversely, target analytes known to bioconcentrate

in fish tissue include cadmium, mercury, and various organochlorinated pesticides and PCBs. In general, higher concentrations of lipids and of all bioconcentratable analytes were detected in higher trophic level piscivorous fish (e.g., the largemouth bass) from Plow Shop Pond than in lower trophic level fish (e.g., the bluegill). Although mercury was detected in all three species of fish analyzed, the highest concentrations were detected in the largemouth bass.

Macroinvertebrate Study. The macroinvertebrate program at the Fort Devens Group 1A sites was designed to provide baseline information regarding the biota associated with aquatic habitats at Plow Shop Pond, and to provide baseline information for possible use in the evaluation of effects and effectiveness of any future remedial actions. Considerable uncertainty is associated with the interpretation of the results of the Group 1A macroinvertebrate study. Limited numbers of samples, uncertainties with the reference ponds, differences in habitat types between ponds, and natural environmental stochasticity confound interpretation of this portion of the supplemental risk assessment.

Statistical analyses of the macroinvertebrate data focused on comparisons between taxa and their abundances either directly, or through the use of species richness, biotic composition, and trophic richness metrics. The results of the macroinvertebrate statistical analysis indicate that Plow Shop Pond may have a significantly lower taxa richness than New Cranberry Pond, the reference site. The study also indicated that New Cranberry Pond may have more pollution-intolerant species than Plow Shop Pond; Plow Shop Pond had a significantly higher percentage of pollution-tolerant dominant taxa in the vegetated substrate. The sampling station farthest from the landfill at Plow Shop Pond appeared to have greater macroinvertebrate biodiversity than stations closer to the landfill. Although no single COPC appears to be impacting the macroinvertebrate community at Plow Shop Pond, a statistical analysis indicates that a group of inorganic COPCs (including both landfill and non-landfill related COPCs, as assessed in this report) may collectively impact the community.

This information suggests that the macroinvertebrate community in Plow Shop Pond, particularly in the vicinity of the landfill, may be slightly impaired relative to that of New Cranberry Pond. However, the uncertainties associated with the macroinvertebrate study confound interpretation of the data.

Plant Impacts. Shepley's Hill Landfill is situated to the south and adjacent to Plow Shop Pond. Two coves extend from the main body of the pond towards the landfill. A red precipitate has historically been observed in the large northern cove and to a lesser extent in the small southern cove; this precipitate has not been observed in any other areas of the pond.

During a 1993 site visit, a contrast was noted between plant communities within these two coves as compared to the greater body of water of Plow Shop Pond. In addition, several dead trees (white pine and red maples) were observed adjacent to the northern cove. No other obvious tree diebacks were observed around the entire perimeter of Plow Shop Pond. Limited qualitative evidence exists suggesting that the aquatic plant life in the northern cove is sparse relative to the rest of the pond; much of the aquatic vegetation in the northern cove was colored by the rust-colored precipitate at the time of the site inspection. At the southern cove, similar observations were made, although the observed impacts were less pronounced.

7.2 COLD SPRING BROOK LANDFILL

The supplemental risk assessment for the Cold Spring Brook Landfill is provided in the following subsections. This revision to the original RI risk assessment (E&E, 1993) includes relevant information obtained through recent studies at the Group 1A sites. A primary objective of the Cold Spring Brook Landfill supplemental risk assessment is to evaluate the potential for adverse environmental effects resulting from exposure to analytes found in fish tissue and sediments in Cold Spring Brook Pond, a wetland adjacent to the landfill. Specifically, the supplemental risk assessment for the Cold Spring Brook Landfill evaluates fish tissue analytical data and aquatic macroinvertebrate community data that were unavailable when the RI report was produced. This assessment also includes a re-analysis of surface water data presented in the original RI report. No additional evaluation of surface soils or groundwater is included in the supplemental ERA for the Cold Spring Brook Landfill.

7.2.1 Summary of RI Risk Assessment

Cold Spring Brook Pond sediments were the primary medium of concern evaluated in the RI ERA. Organic compounds evaluated included PAHs, DDD,

and DDE. Arsenic was the only inorganic analyte present in sediment that was considered in the original ERA. Analytes not evaluated included lead, manganese, and zinc, which were sporadically detected above background levels in sediments (E&E, 1993).

The RI risk assessment (E&E, 1993) indicated that sediment contamination in Cold Spring Brook Pond may pose a risk to ecological receptors. Arsenic was found to be the primary risk contributor to aquatic and semi-aquatic biota. Potential risks to benthic invertebrates and fish were also predicted from DDD.

A summary of the RI risk assessment findings relative to Cold Spring Brook Pond surface water, sediment, and landfill groundwater is presented in Table 7-20. Additional detail regarding the site history, its setting, and the nature of previous investigations can be found in the RI report (E&E, 1993) and in earlier sections of this report.

7.2.2 Conceptual Site Model

In accordance with recent USEPA guidance (USEPA, 1992), a conceptual model has been developed to evaluate how stressors from the Cold Spring Brook Landfill may impact ecological components of the environment in the vicinity of the site (Figure 7-1). This model involves consideration of the ecosystem primarily at risk (Cold Spring Brook Pond), stressor characteristics, and exposure pathways. The exposure scenarios evaluated in the conceptual model consider sources, environmental transport, partitioning of analytes between various environmental media, and identification of exposure routes.

Ecological receptors evaluated in this supplemental risk assessment include aquatic biota (i.e., plants, invertebrates, fish, and amphibians) and semi-aquatic biota (i.e., wildlife that depend on wetlands to meet a portion of their life history requirements). Effects evaluated in the supplemental risk assessment are generally the observed, estimated, or predicted effects of the COPCs on the survival, growth, and reproduction of receptors.

7.2.3 Supplemental Risk Assessment

7.2.3.1 Hazard Assessment. Sampling conducted as part of the RI and supplemental RI at the Cold Spring Brook Landfill has revealed the presence of organic and inorganic analytes in the following environmental media:

- Cold Spring Brook Pond Surface Water
- Cold Spring Brook Pond Sediments
- Cold Spring Brook Pond Fish Tissue
- Groundwater

Analytical data for surface water, sediment, and fish tissue are evaluated in this supplemental RA. No additional consideration of groundwater is included in this report.

Selection of COPCs. Pursuant to USEPA (1989d) guidance, the sediment and fish tissue analytical data for the Cold Spring Brook Landfill were evaluated to determine their validity for use in the risk assessment. All validated analytical data from the RI field investigation were sorted by medium and summarized. Non-detects were assigned one-half the SQL for calculation of average concentrations. The process used to select COPCs was discussed in Section 7.1.2.1.

Surface Water COPCs. The RI risk assessment summarized analytical data from 10 surface water samples from the Cold Spring Brook Landfill site. Nine of these samples were taken from Cold Spring Brook Pond, and one sample was taken from the Cold Spring Brook stream channel downstream of the pond.

In the RI risk assessment, none of the analytes detected in surface water was selected as COPCs. Surface water is re-evaluated in this supplemental RI to provide an indication of the overall risk to aquatic life from exposure to both landfill-related and non-related analytes.

Because no background surface water data are available, no analytes could be eliminated as COPCs based on a comparison to background. Major cations (e.g., calcium, magnesium, potassium, and sodium) were eliminated as COPCs because they are essential dietary nutrients and are generally considered to be of low

toxicity. Although iron also falls within the nutrient category, it was retained as a COPC in surface water because it is a suspected landfill contaminant.

Two organic analytes (alpha-BHC and methylene chloride) were reported as detected in surface water. However, the presence of these analytes is questionable. For example, the concentrations of alpha-BHC presented in the original RI report (E&E, 1993) were footnoted to reflect that these "results were not confirmed on a second column"; therefore, these data are considered highly suspect and this analysis was eliminated as COPC. Methylene chloride was detected in all samples analyzed. However, this is a known laboratory contaminant and was not a analysis of potential concern in groundwater. Therefore it was eliminated as a COPC in Cold Spring Brook Pond surface water.

An uncertainty associated with the evaluation of the E&E (1993) surface water data at Cold Spring Brook Pond is associated with the use of samples analyzed for total, rather than dissolved, contaminants. Recent USEPA national guidance recommends that dissolved contaminant data be used for ecological risk assessments evaluating surface water. Dissolved contaminant data better represent the bioavailable fraction of contaminants present in surface water. Therefore, the use of total contaminant surface water data (rather than the dissolved fraction) results in an over-estimate of risk from surface water at the Group 1A sites.

Surface water COPCs for the Cold Spring Brook Landfill site are presented in Table 7-21.

Sediment COPCs. The original RI report contained summarized analytical data from 10 shallow sediment samples from the Cold Spring Brook Pond Landfill site (E&E, 1993). Nine of the samples were taken in Cold Spring Brook Pond, and one was collected in the Cold Spring Brook east of Patton Road (downstream from Cold Spring Brook Pond). These shallow sediment samples were collected with an Ekman dredge and sampled approximately the top 6 inches of pond sediment.

Sediment samples from 16 additional locations were collected by ABB-ES in December 1992 (see Section 2.0). Much of this second round of sediment sampling in Cold Spring Brook Pond was conducted by vibratory coring

techniques. These techniques provided samples from the top 12 inches of pond sediment.

Ecological exposure to contamination in Cold Spring Brook Pond is likely to be greatest in the top 6 inches of pond sediments. It is unlikely that significant ecological exposure to either floral or faunal receptors occurs in the anoxic interval between 6 and 12 inches. However, in order to best characterize the ecological exposure at the Cold Spring Brook Pond site, and in accordance with an October 20, 1993 Army agreement with state and federal regulators, the 25 shallow sediment samples comprising both data sets were combined. The maximum and average concentrations from this pooled data set served as the ecological exposure point concentrations for the revised risk assessment.

With few exceptions, the COPCs in Cold Spring Brook Pond sediments were detected at higher concentrations during the 1992 ABB-ES sampling program. Only aluminum, iron, manganese, and zinc were detected at higher concentrations during the original RI (E&E, 1993). With the exception of DDT and its degradation products, organics were detected infrequently in both data sets. DDT, DDD, and DDE were detected generally at higher concentrations in the ABB-ES data set. In addition, although the original samples were analyzed for VOCs, the more recently collected samples were not analyzed for VOCs. Evaluating the combined data set consisting of 25 samples generally produces a more representative estimate of average sediment exposure point concentrations.

As discussed in the RI Report (E&E, 1993), the Cold Spring Brook Pond inorganic COPCs in sediments were compared to background soil concentrations because no background sediment database was available. However, because of regulatory concerns regarding the validity of using soils data as a means of screening inorganic analytes in sediment samples, and because no sediments background database has been established and agreed to at Fort Devens, no screening against background has been conducted in the supplemental risk assessment.

Cold Spring Brook Pond sediment COPCs are presented in Table 7-22.

Fish COPCs. Fish sampling and analysis was conducted as described in Section 2.0. Whole fish and fillet tissue burdens were obtained for all three species of fish analyzed. All results are reported on a wet weight basis. Because

fish fillet samples were collected for the purposes of assessing risks to public health, the following subsection discusses whole body tissue analyses only. Summaries of the fish fillet COPCs can be found in Section 6.0.

Summary statistics were calculated to evaluate concentrations of COPCs in nine (three each of pumpkinseed, bullhead, and chain pickerel) whole fish sampled and analyzed from Cold Spring Brook Pond (Table 7-23). Six inorganic analytes (antimony, beryllium, nickel, silver, thallium, and vanadium) were not detected in any Cold Spring Brook Pond whole body tissues analyzed. Copper, iron, manganese, mercury, and zinc were detected in all whole fish tissues analyzed. A total of three pesticides/PCBs were detected in the nine whole fish sampled in Cold Spring Brook Pond (three each of pumpkinseeds, chain pickerel, and bullhead). The sole PCB detected, Aroclor-1254, was found in only one of the nine fish sampled at a concentration of 0.052 μg/kg. The pesticide residues DDE and DDD were found at low concentrations in all fish analyzed.

The fish tissue contaminant burden at Cold Spring Brook Pond was evaluated through empirical and statistical comparisons of Cold Spring Brook Pond whole fish tissue data with data from regional and national studies of fish tissue contaminant burden. Fillet samples were not considered because they were collected primarily for the public health risk assessment (Section 6.0).

MADWPC sources of information used to establish "background" or naturally occurring tissue levels of inorganics and pesticides/PCBs within Massachusetts are summarized in Subsection 7.1.3.1 (under "Fish COPCs") and Appendix N. While their regional source of information is a useful screening tool, it is important to note that there are no MADWPC data available to evaluate several fish tissue COPCs, including arsenic, barium, and cadmium. Information from the USFWS NCBMP (Schmitt et al., 1990; Schmitt and Brumbaugh, 1990) was used to compare Cold Spring Brook Pond fish tissue data to a national database.

A detailed evaluation of Cold Spring Brook Pond fish tissue concentrations relative to regional and national sources of "background" information is presented in Appendix N. Table 7-24 summarizes this evaluation.

Average concentrations of DDE, iron, manganese, and zinc in fish from Cold Spring Brook Pond were significantly higher than average tissue concentrations in the MADWPC database. No other statistically significant differences were noted

between Cold Spring Brook Pond fish and the regional source of information. With the exception of mercury in the pumpkinseed, none of the maximum concentrations of the inorganics, pesticides, or PCBs detected in bullheads or pumpkinseeds from Cold Spring Brook Pond exceeded national 85th percentile concentrations. However, maximum concentrations of mercury and zinc in chain pickerel from Cold Spring Brook Pond exceeded the national 85th percentile concentration. Mercury was found in all three chain pickerel analyzed, at a maximum concentration of 0.47 $\mu g/g$ wet weight. This concentration is approximately 2.8 times the NCBMP 85th percentile concentration for mercury. The average Cold Spring Brook mercury tissue concentrations were less than the subset of MADWPC data evaluated.

Fish body weight and trophic status appears to be a good predictor of mercury contaminant burden in Cold Spring Brook Pond, with higher trophic level species (e.g., the chain pickerel) having higher concentrations of this analyte.

7.2.3.2 Ecological Characterization. The purpose of the ecological characterization is to describe the habitats and potential ecological receptor species that may be exposed to COPCs associated with the Cold Spring Brook Landfill. The presence of rare, threatened, and endangered receptors within (and adjacent to) the study area is also included in this section. This characterization is based on earlier descriptions of the site ecology in the RI report (E&E, 1993), as well as on information collected since the RI was completed. The information included in this subsection is used as the basis for identification of relevant exposure pathways and the selection of appropriate indicator species in the ecological exposure assessment.

Additional detail regarding the regional characterization of Fort Devens is presented in the risk assessment for the Shepley's Hill Landfill (Subsection 7.1.3.2).

Site Description: Cold Spring Brook Landfill. An ecological characterization of the Cold Spring Brook Landfill was conducted as part of the RI field investigation (E&E, 1993). This characterization included the identification of plant and animal communities known to be present at the site, and observations of any actual or potential effects of site contaminants on the site's ecological resources. A summary of the major habitat types and dominant plant species identified during the RI at the Cold Spring Brook Landfill is presented in Table 7-25.

The primary focus of the supplemental risk assessment is to evaluate risk to ecological receptors in Cold Spring Brook Pond. Therefore, summaries of the major wetland habitat types associated with this pond are presented below. Additional detail regarding the wetlands at the site may be found in the wetlands functional assessment (Appendix O).

Forested Wetland. According to the original RI risk assessment, forested wetland habitats are all located downgradient of the landfill and occupy three primary locations: the northern perimeter of the pond, both shorelines of the brook, and the northeast corner of the landfill. The vegetation that characterizes and dominates the forested wetland includes red maple (*Acer rubrum*), white pine (*Pinus strobus*), American hazelnut (*Corylus americana*), and silky dogwood (*Cornus amomum*).

Emergent/Open Water Wetland. Two small emergent wetlands are located downgradient of the Cold Spring Brook Landfill. Flora that characterize this wetland include swamp loosestrife (*Decadon verticillatus*), broad-leaf cattail (*Typha latifolia*), purple loosestrife (*Lythrum salicaria*), purple iris (*Iris versicolor*), silky dogwood, and marsh fern (*Thelypteris palustris*).

Emergent/Open Water Wetland. Cold Spring Brook Pond, a eutrophic and shallow waterbody, was classified in the original RI report as a floating-leaved deep marsh. The pond is located due north and downgradient of the landfill. Dominant flora includes sweet water lily (*Nymphaea odoratus*), water shield (*Brasenia schreberi*), water marigold (*Megalodonta beckii*), swamp loosestrife, and cattail.

Scrub/Shrub Wetland. Two scrub/shrub wetlands are located downgradient of the landfill in the western portion of the pond. Characteristic plant species in this wetland included red maple, smooth alder (*Alnus rugosa*), buttonbush (*Cephalanthus occidentals*), marsh fern, sedge (*Carex* spp.), and meadowsweet (*Spiraea latifolia*).

A WET evaluation was conducted on Cold Spring Brook Pond to assess the functions and values of this wetland. WET is a standardized evaluation technique that provides a rapid assessment of many of the recognized values and functions of a wetland (Adamus et al., 1991). WET uses a standardized manual and answer

sheet to provide input data for the WET 2.0 computer program. After data are entered into the WET program, a "Low," "Medium," or "High" value is assigned to each function.

A combination of the following 11 functions (i.e., physical, , and biological characteristics) and values (characteristics beneficial to society) were evaluated through WET at Cold Spring Brook Pond:

- Groundwater Recharge
- Groundwater Discharge
- Floodflow Alteration
- Sediment Stabilization
- Sediment/Toxicant Retention
- Nutrient Removal/Transformation
- Production Export
- Wildlife Diversity/Abundance
- Aquatic Diversity/Abundance
- Uniqueness/Heritage
- Recreation

The above-listed functions and values were evaluated by WET in the following contexts: "Social Significance" (the value of the wetland to society); "Effectiveness" (the capability of the wetland to provide the function); and "Opportunity" (the opportunity of the wetland to provide the function).

The WET analysis determined that the value to society of Cold Spring Brook Pond is "high" for Wildlife Diversity and Abundance, as well as for Uniqueness and Heritage. The remainder of the evaluated WET parameters were rated "low" in social significance. In terms of effectiveness, WET scored Cold Spring Brook Pond as "high" for Sediment/Toxicant Retention, Nutrient Removal/ Transformation, and Wildlife Breeding and Migration, and as "moderate" for Groundwater Discharge, Floodflow Alteration, and Production Export. The effectiveness of Cold Spring Brook Pond to provide several other functions and values was rated as "low" by WET. Of the three functions/values evaluated for Opportunity, the opportunity for Cold Spring Pond to perform the Sediment/ Toxicant Retention and Nutrient Removal/Transformation functions is rated as "high" by WET. Cold Spring Pond has the opportunity to provide these functions because of the proximity of the adjacent landfill. Floodflow Alteration is rated as

"moderate" by WET based upon the high percentage of the watershed this wetland occupies.

The WET functional assessment is included as Appendix O. In addition, this appendix includes a narrative discussion interpreting the results of the WET analysis.

Rare, Threatened, and Endangered Species. The presence or absence of rare and endangered flora and fauna at the site is reviewed in this subsection. As detailed in Subsection 7.1.3.2, ABB-ES has developed a database of all flora and fauna known to seasonally or permanently occur at, or migrate through, Fort Devens (ABB-ES, 1992). The Fort Devens biological database contains current information from the MNHP and the USFWS regarding all rare and endangered species known to occur at Fort Devens. In addition, the ABB-ES database contains records that have not yet been incorporated into the MNHP database.

The ABB-ES master biological database has been checked for the vicinity of Cold Spring Brook Landfill. No records were located for the site or its immediate vicinity.

Fish Community Study. As a supplemental RI activity, ABB-ES personnel conducted a qualitative study of the fish population at Cold Spring Brook Pond. The fish evaluation was designed to provide baseline information regarding the species of fish present, relative abundance of the species present, fish size distribution, trophic structure of the fish community, and the presence or absence of recreationally important fish. The fish evaluation was not intended to provide an inventory or survey of all fish present in the ponds, but to serve as a means of gathering baseline information regarding the Cold Spring Brook fishery. The fish sampling program is described in the Section 2.0. Appendix N contains an evaluation of the fish size distribution in Plow Shop Pond, as well as an evaluation of fish tissue contaminant concentrations relative to source of "background" information.

A total of 95 fish representing five families and six species were collected in Cold Spring Brook Pond (Table 7-26 and Figure 7-7). The golden shiner (*Notemigonus crysoleucas*) was the predominant fish sampled, comprising 59 percent of the total population and 24 percent of the fish biomass sampled in Cold Spring Brook. Sunfish (pumpkinseed [*Lepomis gibbossus*] and black crappie [*Pomoxis*

nigromaculatus], both members of the Centrarchidae) accounted for approximately one-quarter of the total number of fish captured in Cold Spring Brook Pond, and one-fifth of the total fish biomass sampled.

The top predator sampled in Cold Spring Brook Pond was the chain pickerel (*Esox niger*), which represented approximately 8 percent of the total numbers of fish collected. No largemouth bass were collected in Cold Spring Brook Pond. Seven yellow bullhead (*Ictalurus natalis*) and an American eel (*Anquilla rostrata*) were also collected from Cold Spring Brook Pond during the sampling program.

Two insectivorous species (yellow bullhead and pumpkinseed), and three insectivore/piscivore species (black crappie, American eel, and chain pickerel) were collected from the pond. Insectivorous fish accounted for approximately 25 percent and insectivore/piscivore species accounted for approximately 16 percent of the pond's fish community. The golden shiner (*Notemigonus crysoleucas*), an omnivore, the dominant fish species collected, represented approximately 59 percent of the sampled population.

The species composition and taxa richness of Cold Spring Brook Pond is typical of a southern New England warm water fish community. The numbers of individual fish collected at Cold Spring Brook Pond was typical of sampling efforts in small lake habitats throughout southern New England (Downey, 1993). Based on the results of this qualitative study, Cold Spring Brook Pond is characterized by fewer species of fish than Plow Shop Pond. An omnivorous species, the golden shiner, may be more abundant in Cold Spring Brook Pond than in Plow Shop Pond. These differences are likely reflective of the one-day sampling effort at the much smaller pond, rather than of any landfill-related impacts.

Macroinvertebrate Study. As was done at Plow Shop Pond (see Subsection 7.1.3.2), a semi-quantitative inventory of macroinvertebrates was conducted at three sampling stations in Cold Spring Brook Pond (Figure 2-10). At each sampling station, two duplicate macroinvertebrate samples from vegetation ("phytomacrofauna") and two duplicate samples from sediment ("benthic infauna") were collected. All macroinvertebrate samples from Cold Spring Brook Pond were collected on September 24 and 25, 1992, using sampling and processing methods outlined in Section 2.0.

The macroinvertebrate study at Cold Spring Brook Pond was designed to meet the identical objectives to those at Plow Shop Pond:

- to determine the presence or absence of macroinvertebrate infauna;
- to gather information about population density and taxonomic diversity; and
- to statistically evaluate the relationship between the macroinvertebrate community characteristics of the potentially impacted pond and the concentrations of analytes found in the sediment.

However, as discussed elsewhere (i.e., ABB-ES, 1993a and Subsection 7.1.3.2), considerable uncertainty is associated with the interpretation of the results of the Group 1A macroinvertebrate study. Limited numbers of samples, uncertainties associated with the selected reference pond, differences in habitat types between ponds, and natural environmental stochasticity confound interpretation of this portion of the supplemental risk assessment.

Information regarding the physical attributes of the aquatic habitat (including nature of the substrate and vegetative characteristics) and water quality parameters (i.e., dissolved oxygen, temperature, pH, and conductivity) were collected at each sampling station and are summarized in Table 7-8.

As discussed previously, New Cranberry Pond was selected as the reference pond for the macroinvertebrate study. An analysis of New Cranberry Pond sediment chemistry data from the macroinvertebrate sampling stations indicates that lead, mercury, DDT, DDE, and DDD may exceed available sediment quality criteria and guidance values (Table 7-11). It is possible that some or all of these exceedances represent a "background" level of analytes (particularly pesticides) on South Post, rather than a hazardous waste site-related problem, and that the pesticide sediment quality criteria are overly conservative for use at Fort Devens (see Appendix S). A summary of the Cold Spring Brook and New Cranberry Pond sediment chemistry from the macroinvertebrate sampling locations is presented in Table 7-27.

Based on these exceedances, uncertainty is associated with using New Cranberry Pond as an un-impacted reference station. However, because the New Cranberry Pond sediment contaminant burden is generally lower than that of Cold Spring Brook Pond, the macroinvertebrate study was conducted with New Cranberry Pond as a reference pond.

General water quality parameter data from Cold Spring Brook Pond were compared to those collected from New Cranberry Pond to determine if any of these parameters could have contributed to or influenced the results of the benthic community evaluation. In general, water quality parameter data from stations at Cold Spring Brook Pond differ little from those at New Cranberry Pond.

The pH at both ponds was fairly close to neutral, ranging from 7.45 to 8.15 at Cold Spring Brook Pond and 6.54 to 6.69 at New Cranberry Pond. The pH at both ponds was within the chronic AWQC range for pH of 6.5 to 9 (USEPA, 1986). Both DO and temperature at Cold Spring Brook Pond were higher than at New Cranberry Pond, which may be anomalous given that DO generally decreases with increasing temperature (Connell and Miller 1984). The most marked difference between the two ponds was conductivity, which ranged from 240 to 297 microsiemens at Cold Spring Brook Pond and 43.6 to 49.6 microsiemens at New Cranberry Pond. This suggests a higher concentration of dissolved salts or suspended solids in Cold Spring Brook Pond, which could be reflective of differences in surface water quality.

General water quality parameter data from each pond were also evaluated to identify potential differences or trends associated with proximity to the landfill source. The general water quality parameters measured at the three stations within Cold Spring Brook Pond did not vary greatly (Table 7-8).

Eutrophic New England ponds exhibit a wide variety of pH, temperature, and DO conditions across spatial and temporal gradients, and resident organisms must be able to tolerate these diverse conditions. With the possible exception of conductivity, the general water quality parameters do not appear to be influencing factors in the differences observed between the macroinvertebrate communities at the two ponds or at the different stations within a pond.

A checklist of Fort Devens macroinvertebrates is found in Table 7-11. Macroinvertebrate communities are characterized by considerable spatial and temporal diversity. Therefore, the taxa listed in Table 7-11 represent the assemblage that was collected during the sampling effort, and are not representative of or intended to be used as a true checklist for Cold Spring Brook Pond or any other aquatic resources at Fort Devens.

Statistical evaluation of the Fort Devens macroinvertebrate data included the following techniques:

- Kruskal-Wallis tests of variance
- Analyses of Variance (ANOVAs) with Tukey's Studentized Range
- Clustering analyses
- Rapid Bioassessment Protocol (RBP) metric comparison
- Taxonomic similarity testing with Jaccard Coefficients of Community Similarity
- Simple linear regression
- Multiple linear regression

These analyses focused on comparisons between taxa and their abundances either directly, or through the use of species richness, biotic composition, and trophic richness metrics. A detailed presentation of the Fort Devens macroinvertebrate statistical community analysis is presented in Appendix P and in Subsection 7.1.3.2.

The following metrics were calculated for the phytomacrofauna and benthic substrate samples: taxa richness, modified FBI, ratio of EPT/C abundances, percentage contribution of the dominant family, and the EPT index (Tables P-1a, P-2a, P-3a and P-1b, P-2b, P-3b). In addition, a Jaccard Coefficient of similarity (Table P-6), statistical analysis of macroinvertebrate abundance (Tables P-7, P-8, and P-9), and a cluster analysis were done on the data (Figure P-1). Finally, a percentage comparability ratio was calculated, as described in the USEPA RBP manual (Plafkin et al., 1989) (Tables P-4 and P-5).

New Cranberry Pond, the reference site, had a slightly higher taxa richness than Cold Spring Brook Pond (Tables P-2a and P-2b). New Cranberry Pond phytomacrofauna samples also had a lower FBI than the Cold Spring Brook Pond samples. This suggests that New Cranberry Pond may have more

pollution-intolerant species than Cold Spring Brook Pond. However, the RBP-III percentage comparability analysis (Table P-4) indicated that Cold Spring Brook Pond was non-impaired, relative to New Cranberry Pond.

The Jaccard Coefficients indicated that the two macroinvertebrate communities at the stations sampled closest to the Cold Spring Brook Landfill were most similar to each other (Table P-6). The stations farthest from the landfill had greater macroinvertebrate biodiversity. Statistics done on the abundance of macroinvertebrates showed a similar result: the stations nearest to the landfill in Cold Spring Brook Pond may have reduced macroinvertebrate abundance relative to the station furthest from the landfill (Table P-8). The results of the cluster analysis were in accordance with the preceding analyses. This analysis may suggest that the closer a station within the pond was to the landfill, the greater the impact to the macroinvertebrate community (Figure P-1).

An analysis of the relationships between sediment chemistry and macroinvertebrate abundance, as well as diversity metrics, was inconclusive (Tables P-10 through P-17). This analysis suggested that no relationship exists between levels of the organic pesticides DDD, DDE, and DDT and differences in macroinvertebrate abundance and diversity in the study ponds. In addition, the sediment chemistry analysis indicated that no single inorganic COPC seems to be affecting the macroinvertebrate communities at the Group 1A sites. However, the statistical analysis did indicate that a group of approximately fifteen inorganic analytes may impact the macroinvertebrates community. These include arsenic, barium, beryllium, cadmium, copper, chromium, iron, mercury, manganese, nickel, antimony, and zinc. The statistical analysis suggested that arsenic, cobalt, iron, manganese, and mercury may be the five inorganic COPCs of primary concern, relative to macroinvertebrate community abundance and diversity.

In summary, the RBP-III percentage comparability analysis indicated that Cold Spring Brook Pond was non-impaired relative to New Cranberry Pond. However, statistical analyses indicated that the Cold Spring Brook Pond macroinvertebrate community may be slightly impaired relative to that of New Cranberry Pond. The data suggest that the macroinvertebrate stations closest to the landfill may be more impacted relative to the station furthest from the landfill.

Considerable uncertainty is associated with the macroinvertebrate study at Fort Devens. This uncertainty is discussed in Subsection 7.3.

7.2.3.3 Ecological Exposure Assessment. The purpose of the ecological exposure assessment in this supplemental risk assessment is to evaluate the potential for ecological receptor exposure to constituents in fish tissue, surface water, and sediments at the Cold Spring Brook Landfill site. Ecological exposures to other environmental media have been previously evaluated in the original RI (E&E, 1993). This evaluation involves the identification of actual or potential exposure routes to receptors at Cold Spring Brook Landfill and evaluation of the magnitude of exposure to identified ecological receptors. In the exposure assessment, exposure concentrations are estimated for each receptor and for each exposure pathway evaluated in the supplemental risk assessment. This exposure information is used in conjunction with the toxicological information presented in the ecological effects assessment to evaluate ecological risk. Ecological exposure pathways evaluated for the Cold Spring Brook Pond Landfill are identical to those evaluated at the Shepley's Hill Landfill and are presented in Subsection 7.1.3.3.

Receptors for which exposure and risks have been quantified include:

- Aquatic biota in Cold Spring Brook Pond
- Semi-aquatic biota that depend on the aquatic environment for a portion of their life history requirements (i.e., wetlands wildlife)

Aquatic Biota. As discussed in Subsection 7.1.3.3, the exposure point concentrations employed in this supplemental risk assessment are the maximum and average concentrations of COPCs in surface water and sediment.

Semi-aquatic Biota. As discussed in Subsection 7.1.3.3, to evaluate food chain exposure to semi-aquatic ecological receptors at the Group 1A sites, a simple food web model was employed to estimate the potential dietary exposure levels of sediment analytes. Estimated tissue residues in prey items were calculated using BAFs, as detailed in Subsection 7.1.3.3. The semi-aquatic ecological receptor species evaluated in the Cold Spring Brook Pond food web model were identical to those evaluated at Plow Shop Pond, with the exception of the osprey. The osprey was not evaluated at Cold Spring Brook Pond because it is unlikely that this piscivore would hunt at this small water body.

Estimated contaminant tissue residues in prey species were estimated by multiplying either the average (for the average exposure scenario) or the

maximum (for the RME scenario) sediment analyte concentrations by specific BAFs, as detailed in Subsection 7.1.3.3.

To estimate dietary exposure concentrations for the modeled receptors under the average exposure scenario, the potential food chain exposure point concentration in fish tissue is therefore the average analyte concentration detected in Cold Spring Brook Pond fish. For the RME scenario, a conservative assumption has been made that the fish tissue exposure point concentration is greater than the average COPC concentrations detected in fish tissue.

The PED level associated with ingestion of contaminated prey items for each modeled receptor species was calculated by multiplying each predicted prey species tissue concentration by the proportion of that prey type in the diet, summing these values, multiplying by the receptor species' SFF, ED, and IR, and dividing by the receptor species' BW. The PED_{diet} is represented by the equation presented in Subsection 7.1.3.3.

Potential exposure dosages for the incidental sediment ingestion pathway ($PED_{sediment}$) (i.e., associated with foraging, preening, and cleaning activities) were estimated by multiplying the sediment concentrations by the estimated percentage of sediment in the diet of each modeled receptor species, multiplying by the SFF, ED, and ingestion rate, and dividing by BW. For the receptors evaluated at Cold Spring Brook Landfill, incidental sediment ingestion was conservatively assumed to range from 0 to 5 percent of the receptor's dietary intake, based in part on a recent presentation of Beyer and Connor (1992). The area of contaminated pond was assumed to be 3.5 acres (the entire pond) for the purpose of calculating the SFF.

Exposure dosages associated with these two pathways were summed to calculate a TBD:

$$TBD = PED_{diet} + PED_{sediment}$$

where:

TBD	=	Total Body Dose (mg/kgBW-day)
PED_{diet}	=	Potential Dietary Exposure Dosage (mg/kgBW-day)
$PED_{sediment}$	=	Potential Sediment Exposure Dosage (mg/kgBW-day)

TBD estimates, expressed in mg/kgBW-day, are directly comparable to the available toxicological dose-response data and were used in conjunction with toxicological data to evaluate ecological risks to semi-aquatic receptors at Cold Spring Brook Pond.

7.2.3.4 Ecological Effects Assessment. The purpose of the Ecological Effects Assessment is to select the ecological characteristics (endpoints) to be evaluated, to describe the environmental risks associated with the identified COPCs in each medium of concern, and to evaluate the relationship between the concentration to which an organism is exposed and the potential for adverse effects. The toxicological evaluation includes the process of characterizing the inherent toxicity of the COPCs and establishing reference or threshold toxicity values for each identified analyte. Information contained in the ecological effects assessment, in conjunction with exposure information presented in the previous subsection, is used to evaluate ecological risks to aquatic and semi-aquatic organisms in the ecological risk characterization.

This subsection addresses the potential effects of COPCs in Cold Spring Brook Pond surface water, sediments, and fish tissue. In addition, relevant aspects of the supplemental RI ecological field program, as presented in Section 2.0, are discussed in the context of providing corroborative evidence between COPC exposures and ecological effects.

Selection of Endpoints. The first component of the Ecological Effects Assessment consists of identifying ecological characteristics or endpoints that may be adversely affected by exposure to an environmental stressor (for instance, a COPC). Two types of ecological endpoints were considered: assessment endpoints and measurement endpoints (Suter, 1993; USEPA, 1992c). Assessment endpoints formally describe the environmental value(s) to be protected. In most cases, the assessment endpoint could not be directly measured at Cold Spring Brook Pond, and a measurement endpoint (or suite of measurement endpoints) has been selected that can be related, either qualitatively or quantitatively, to the assessment endpoint (USEPA, 1992c).

Additional detail regarding assessment and measurement endpoints can be found in the Plow Shop Pond risk assessment (Subsection 7.1.3.4).

Toxicity to Aquatic Receptors. As discussed in Subsection 7.1.3.4, the risk to aquatic receptors from Cold Spring Brook Pond surface water and sediment contamination has been evaluated through comparison of concentrations of analytes present in these media to available surface water and sediment quality criteria or guidance values, which serve as the benchmark concentration RTVs for these media.

Summaries of surface water and sediment benchmark concentration RTVs for Cold Spring Brook Pond are presented in Tables 7-28 and 7-29, respectively.

Toxicity to Semi-aquatic Receptors. As discussed in the Plow Shop Pond risk assessment (Subsection 7.1.3.4), potential impacts to semi-aquatic ecological receptors at estimated exposure concentrations were evaluated using published laboratory-derived toxicological data, as well as threshold toxicity values developed using extrapolation techniques. Toxicological endpoints evaluated included behavioral effects, developmental effects, physiological changes, and changes in organ weight, size, or functionality. Lethal concentration and dose studies (e.g., LD_{50} studies) and effects studies (e.g., EC_{50} studies) were considered.

Toxicological benchmark RTVs are presented in Appendix Q, Tables Q-3 and Q-4. The rationale behind the selection of the appropriate benchmarks is presented in Subsection 7.1.3.4.

Field Observations. Limited measurement endpoint data are available from the qualitative fish population study and the semi-quantitative macroinvertebrate community study. The macroinvertebrate study has been summarized in Subsection 7.1.3.2 and in Appendix P.

As detailed in Sections 2.0 and 7.2.3, fish were collected from Cold Spring Brook Pond to provide baseline information regarding the status of the fishery in the pond. Interactions between analytes and fish populations are poorly understood, and no single pathological condition in individual fish or in fish populations serves as a universal contaminant stress indicator (Hunn, 1988). However, certain physical, anatomical, bio, and physiological conditions are known to be associated with environmental pollutants. These conditions include fin erosion, skin ulcerations, skeletal abnormalities, tumors, and scale disorientation (Hunn, 1988).

As part of the fish study, a number of individual fish were checked for external pathological gross abnormalities (e.g., tumors, lesions, structural or bone defects) through an evaluation of the conditions of the lips, jaws, barbels (when applicable), eyes, right gill, fins, urogenital cavity, anus, body form, and body surfaces. All data were recorded on field data sheets.

The gross pathological examination of fish from Cold Spring Brook Pond suggests that the individual fish evaluated were healthy (Table 7-30). No tumors or lesions were observed in any fish examined; barbels on all bullheads examined were uniformly intact and free from abnormalities. Of the 73 fish examined, three exhibited minor physical abnormalities. A slight frayed opercle was noted in one pumpkinseed, a golden shiner was missing part of the caudal fin, and a second golden shiner exhibited a bruise near its anal fin. These conditions are commonly observed in many non-stressed fish populations.

7.2.3.5 Ecological Risk Characterization. This subsection characterizes the risk to aquatic and aquatic receptors potentially exposed to COPCs in Cold Spring Brook Pond surface water, sediment, and fish tissue. Risks were quantitatively evaluated using HQs, which were calculated for each COPC by dividing the estimated exposure concentration or dose by the concentration or dosage benchmark RTV.

RME and average exposure HQs for aquatic organisms were estimated by dividing the maximum and average environmental concentrations, respectively, of each COPC by the concentration RTV (typically a surface water or sediment quality criterion or guideline). To calculate RME HQs for the semi-aquatic organisms evaluated through food web modeling, the dose based on the maximum concentration of each COPC was divided by the dosage RTV. Average exposure HQs were calculated by dividing the dose based on the average COPC concentrations by the appropriate dosage RTV. Summary HIs were determined by summing the HQs for all COPCs.

Additional detail regarding the HQ approach can be found in the Plow Shop Pond (Shepley's Hill Landfill) risk assessment (Subsection 7.1).

Risk to Aquatic Receptors From Surface Water. Comparison of the Cold Spring Brook Pond surface water COPC concentrations with RTVs provides a means to evaluate the potential for adverse effects to aquatic receptors from exposure to

COPCs (Table 7-31). This comparison indicates that aquatic life in Cold Spring Brook Pond may potentially be at risk from exposure to contaminated surface water.

An uncertainty associated with the evaluation of the E&E (1993) surface water data is associated with the use of samples analyzed for total, rather than dissolved, contaminants. Recent USEPA national guidance recommends that dissolved contaminant data be used for ecological risk assessments evaluating surface water. Dissolved contaminant data better represent the bioavailable fraction of analytes present in surface water. Therefore, the use of total contaminant surface water data (rather than the dissolved fraction) results in an over-estimate of risk from surface water at Cold Spring Brook Pond.

The average concentrations of iron and silver exceeded the chronic criteria for these analytes. The maximum concentration of iron is below the acute RTV (which was derived from the chronic RTV by applying a factor of 0.1, as discussed previously). This indicates the potential for chronic, but not acute toxic effects, in aquatic organisms sensitive to iron. The maximum concentration of zinc exceeded the acute criterion for this analyte indicating the potential for acute toxic effects in organisms occurring in surface waters with this concentration. Given that only a small fraction of any aquatic population is likely to be exposed to a maximum concentration, adverse ecological impacts (i.e., adverse impacts at the population and community levels) are considered unlikely.

It is important to note that AWQC for zinc incorporate data from studies using sensitive coldwater species such as rainbow trout which do not occur in the fish community in Cold Spring Brook Pond. These criteria may therefore be overprotective of species such as shiners and sunfish, which are generally less sensitive to environmental contaminants. The average and RME hazard indices are 5.0 and 4.0 respectively. These findings suggest that risks to aquatic life in Cold Spring Brook Pond from exposure to COPCs are possible, but unlikely.

Risks To Aquatic Receptors from Sediment. Comparison of the Cold Spring Brook Pond sediment COPC concentrations with concentration RTVs provides a means to evaluate the potential for adverse effects to aquatic environmental receptors from exposure to COPCs (Table 7-32). This comparison indicates that aquatic life may be slightly at risk from exposure to contaminated sediments in Cold Spring Brook Pond.

Concentrations of anthracene, DDD, DDT, arsenic, barium, lead, and manganese, exceeded the available sediment RTVs under average exposure and RME assumptions. The average exposure HQs for these analytes ranged from 1.5 (mercury) to 4.2 (DDT). Concentrations of silver, iron, mercury, nickel and zinc exceeded RTVs under RME assumptions. REM HQs ranged from 1.8 (nickel) to 98.7 (DDT). However, this high DDT HQ is associated with the DDT detected in one sample (CSD-92-01 at 15 $\mu g/g$), which is several orders of magnitude higher than DDT concentrations elsewhere in Cold Spring Brook Pond.

As detailed in Appendix S, the interim sediment quality criteria for DDD, DDE, and DDT may be too conservative for use at Cold Spring Brook Pond. If the proposed site specific value of 2.58 $\mu g/g$ is used as the pesticide sediment quality criteria for Cold Spring Brook Pond, no risk is predicted for aquatic receptors from the average exposure scenario. Using the proposed site-specific interim sediment quality criteria, the HQ for DDD would decrease from over 40 to 2.4, the HQ for DDE would decrease from 4.7 to 0.3, and the DDT HQ would decrease from 98.7 to 5.8.

Risks to Semi-aquatic Receptors. Risks to semi-aquatic receptors at Cold Spring Brook Landfill were evaluated through use of a food web exposure model. Analyte-specific TBDs for each model receptor species were calculated as described in Subsection 7.2.3.3, and provide an estimate of the combined effects of exposure to sediment and the consumption of contaminated prey items. The TBD for each constituent was compared to the dosage RTV to develop average exposure and RME HQs. For each species evaluated, HIs were determined by summing the HQs for all COPCs (Table 7-33). Estimates of exposure and risk to semi-aquatic receptors at the Cold Spring Brook Landfill are presented in Appendix R, Tables R-9 through R-12.

For both the average exposure and RME scenarios at Cold Spring Brook Pond, no HQs were greater than 1 for any of the seven semi-aquatic receptor species evaluated. Under RME assumptions, HIs were greater than 1 for the mallard (HI = 1.4) and green frog (HI = 2.4) (Table 7-33).

These findings suggest that individual COPCs from Cold Spring Brook Landfill are not resulting in adverse ecological risk to semi-aquatic receptors at this site. However, the RME summary HIs for the green frog and mallard are slightly greater than 1, indicating that it is possible, but unlikely, that individual animals

exposed to maximum concentrations of all Cold Spring Brook Pond COPCs may be at risk. Population level impacts are unlikely to result from exposures of individual animals to maximum concentrations.

Field Program Risk Characterization. Considerable uncertainty is associated with evaluation of several of the measurement endpoints in the fish and macroinvertebrate studies. Inherent environmental variability limits the use of measurement endpoints evaluated in the ecological field program. However, limited measurement data from the macroinvertebrate community study and the fish study are available to assist with risk characterization at the Cold Spring Brook Landfill.

The fish community study was qualitative in nature and was not intended to provide an inventory or survey of all fish in Cold Spring Brook Pond. However, as detailed in Subsection 7.2.3.2, the results of the qualitative fish community study suggest that the fish species composition and taxa richness of Cold Spring Brook Pond is characteristic of typical small southern New England ponds. A total of 95 individual fish representing five families and six species were captured in the pond. Top predators, including the chain pickerel, as well as various insectivorous and omnivorous were abundant in Cold Spring Brook Pond.

The gross pathological evaluation of the fish community also was not designed to quantitatively evaluate all sub-lethal indicators of contaminant stress. However, the results of this evaluation suggest that, in terms of gross external pathological indicators, the members of the fish population evaluated from Cold Spring Brook Pond were healthy. A total of 73 fish from Cold Spring Brook Pond were inspected for gross pathological abnormalities (i.e., tumors, lesions, structural, or bone defects). No tumors, lesions, ulcerations, skeletal anomalies or other gross pathological conditions associated with contaminant stress were found in any fish examined.

In general, the lower trophic level fish species evaluated (e.g., the pumpkinseed) contained higher average concentrations of iron than did higher trophic level species. This may reflect the fact that these fish are omnivorous and are obtaining iron from plant food sources (Moore, 1991). Conversely, higher concentrations of lipids and of bioconcentratable analytes (e.g., mercury) were detected in higher trophic level fish (e.g., the chain pickerel). However, the concentrations of mercury in Cold Spring Brook Pond fish were considerably

lower than the concentrations detected in the large piscivores from Plow Shop Pond.

Macroinvertebrate Study. The macroinvertebrate program at the Fort Devens Group 1A sites was designed to provide baseline information regarding the biota associated with aquatic habitats at Cold Spring Brook Pond, and to provide baseline information for possible use in evaluation of effects and effectiveness of any future remedial actions. Considerable uncertainty is associated with the interpretation of the results of the Group 1A macroinvertebrate study. Limited numbers of samples, uncertainties with the reference ponds, differences in habitat types between ponds, and natural environmental stochasticity confound interpretation of this portion of the supplemental risk assessment.

Statistical analyses of the macroinvertebrate data focused on comparisons between taxa and their abundances either directly, or through the use of species richness, biotic composition, and trophic richness metrics. The results of the macroinvertebrate statistical analysis are somewhat nebulous. While the RBP-III percentage comparability analysis indicated that Cold Spring Brook Pond was non-impaired relative to New Cranberry Pond, other statistical analyses indicate that the Cold Spring Brook Pond macroinvertebrate community may be slightly impaired with respect to abundance and taxa diversity. The data also suggest that the macroinvertebrate stations closest to the landfill may be more impacted relative to the station furthest from the landfill.

7.3 Ecological Uncertainty Analysis

The prediction of ecological risks at the Fort Devens Group 1A sites involves a number of uncertainties. Many of these uncertainties are inherent in the risk assessment process; others are specific to the Shepley's Hill Landfill and Plow Shop Pond risk assessments. Table 7-34 summarizes the uncertainties identified for the ERA.

As in the original RI risk assessments, the principal uncertainties are associated with the ecological exposure and effects assessments, as well as with the risk characterization. In general, the supplemental ERAs are likely to overestimate (rather than underestimate) the risks of adverse ecological effects at the Group 1A sites because of the conservative nature of many of the assumptions used.

7.4 SUMMARY OF SUPPLEMENTAL RISK ASSESSMENTS

Supplemental risk assessments were performed at the Shepley's Hill Landfill and Cold Spring Brook Landfill to update the original ERAs (E&E, 1993). The supplemental ERAs integrated information gathered from several phases of site investigation at the Group 1A sites to determine whether environmental contaminants may pose a risk to ecological receptors. Specifically, the supplemental risk assessment evaluated sediment and fish tissue analytical data that were unavailable when the original RI report was produced. A reevaluation of available surface water data was also conducted. No additional evaluation of surface soils or groundwater was included in the supplemental ERAs.

7.4.1 Shepley's Hill Landfill

The original risk assessment (E&E, 1993) indicated that sediment contamination from the landfill-derived inorganic analytes in Plow Shop Pond may pose a risk to ecological receptors. Arsenic was found to be the primary risk contributor to aquatic and semi-aquatic biota. Risks to aquatic biota were also predicted from cadmium.

To further evaluate ecological risk from the Shepley's Hill Landfill, analytical chemistry data from 41 shallow sediment samples and 15 individual whole fish (representing three species) were evaluated in the supplemental risk assessment. The following sections summarize the results of this supplemental evaluation.

7.4.1.1 Fish Sampling Program. The average fish tissue concentration from Plow Shop Pond exceeded regional averages for the following analytes: DDE, aluminum, iron, manganese, mercury, and zinc. The average whole body concentrations of aluminum, iron, manganese, and zinc in Plow Shop Pond fish were significantly greater ($P < 0.05$) than average concentrations from the regional database. The maximum Plow Shop Pond whole fish tissue concentrations of arsenic, cadmium, copper, and mercury exceeded their respective NCBMP 85th percentile concentrations. Fish body weight (and concomitantly trophic status) appears to be a good predictor of mercury contaminant burden in Plow Shop Pond, with higher trophic level fish species having accumulated higher concentrations of this analyte.

A total of 193 fish representing seven families and 12 species were collected in Plow Shop Pond. Top predators, including the largemouth bass and chain pickerel represented more than 10 percent of the total numbers of animals collected. Omnivorous and insectivorous were also well represented in Plow Shop Pond. Based on the data collected in this study, the species composition and taxa richness of Plow Shop Pond is typical of a southern New England warm water fish community. A gross pathological examination of fish from Plow Shop Pond suggests that the individuals from the population examined are healthy. No tumors, lesions, or other significant abnormalities were observed in any fish examined.

7.4.1.2 Macroinvertebrate Sampling Program. The macroinvertebrate program at the Shepley's Hill Landfill was designed to provide baseline information regarding the biota associated with aquatic habitats in Plow Shop Pond. Although some uncertainty was associated with the identified reference pond (New Cranberry Pond), the macroinvertebrate community data suggest that Plow Shop Pond may be slightly impacted relative to New Cranberry Pond. In particular, the macroinvertebrate statistical analysis indicate that Plow Shop Pond may have a significantly lower taxa richness than New Cranberry Pond, the reference site. The study also indicated that New Cranberry Pond may have more pollution-intolerant species than Plow Shop Pond; Plow Shop Pond had a significantly higher percentage of pollution-tolerant dominant taxa in the vegetated substrate. Lastly, the macroinvertebrate sampling station farthest from the landfill at Plow Shop Pond appeared to have greater macroinvertebrate biodiversity than stations closer to the landfill. While no organic analyte concentrations appear to be correlated with macroinvertebrate community abundance metrics, the data suggest that a combination of key inorganic analytes may be affecting the macroinvertebrate community structure.

This information suggests that the macroinvertebrate community in Plow Shop Pond, particularly in the vicinity of the landfill, may be slightly impaired relative to that of New Cranberry Pond. However, considerable uncertainty is associated with the study.

7.4.1.3 Aquatic Receptor Hazard Assessment. Concentrations of all five landfill-related analytes (arsenic, barium, iron, manganese, and nickel) were below the surface water TRVs. The average and RME exposure HIs were 7.7 and 12.8, respectively, due primarily to copper and silver. These findings suggest that any

potential risks to aquatic receptors at Plow Shop Pond as a result of surface water exposures may be primarily attributable to sources other than the Shepley's Hill Landfill. Concentrations of all five landfill-related analytes, as assessed in this report, exceeded the available sediment quality criteria or guidelines. The average exposure HQ for arsenic was 14.2, whereas the RME HQ for this analyte was 97. Average exposure and RME HQs for the other landfill analytes ranged from 1.5 to 128. Other non-landfill related COPCs in Plow Shop Pond sediments were also present in concentrations in excess of their RTVs. HQs ranged from 2 to an RME HQ of 867, for mercury. The RME HQs for cadmium, chromium, cobalt, copper, lead, and zinc were also greater than 1, and ranged from 1.2 (cobalt) to 125 (chromium). For aquatic receptors, approximately 15 percent of the average exposure HI for Plow Shop Pond is attributable to landfill analytes in sediments. The remaining 85 percent of the average exposure HI is contributed from analytes originating from sources other than the Shepley's Hill Landfill, with mercury being the primary contributor to risk.

7.4.1.4 Semi-aquatic Receptor Hazard Assessment. For semi-aquatic wildlife, exposure to average concentrations of arsenic in Plow Shop Pond sediment and fish tissue resulted in an HQ greater than 1 for one of the eight receptor species evaluated in the food web model (the green frog, $HQ_{arsenic} = 1.2$). RME arsenic exposure to the green frog resulted in an HQ of 7.9. With the exception of manganese, none of the other four landfill contaminants (barium, manganese, iron, and nickel), as assessed in this report, have HQs in excess of 1; the RME HQ for the mink exposure to manganese was 4.7. Average and RME exposure to mercury, lead, and chromium, all non-landfill-related COPCs in Plow Shop Pond sediments, were also presumed to result in risks to semi-aquatic receptors, with HQs greater than 1 for the great blue heron, mallard, painted turtle, and green frog.

7.4.1.5 Supplemental Risk Assessment Summary. These findings suggest that analytes detected in Plow Shop Pond may be posing a risk to aquatic and semi-aquatic receptors. Analytes from Shepley's Hill Landfill and from sources other than the Shepley's Hill Landfill are ecological risk contributors to aquatic and semi-aquatic receptors in Plow Shop Pond. Primary risk contributors in Plow Shop Pond include arsenic, chromium, lead, manganese, and mercury.

7.4.2 Cold Spring Brook Landfill

The original risk assessment (E&E, 1993) indicated that sediment contamination in Cold Spring Brook Pond may pose a risk to ecological receptors. Arsenic was found to be the primary risk contributor to aquatic and semi-aquatic biota. Risks to aquatic biota were also predicted from DDD.

To further evaluate ecological risk from the Cold Spring Brook Landfill, analytical chemistry data from 25 shallow sediment samples and nine individual whole fish (representing three species) were evaluated in the supplemental risk assessment. The following sections summarize the results of this supplemental evaluation.

7.4.2.1 Fish Sampling Program. The average fish tissue concentration from Cold Spring Brook Pond exceeded regional averages for the following analytes: DDE, iron, manganese, and zinc. This difference was statistically significant ($P < 0.05$). The maximum Cold Spring Brook Pond whole body chain pickerel concentrations of mercury and zinc exceeded their respective NCBMP 85th percentile concentrations. Fish body weight (and concomitant trophic status) appears to be a good predictor of mercury contaminant burden in Cold Spring Brook Pond, with higher trophic level fish species having accumulated higher concentrations of this analyte.

A total of 95 fish representing five families and six species were collected in Cold Spring Brook Pond. The golden shiner (*Notemigonus crysoleucas*) was the predominant fish sampled, comprising 59 percent of the total population sampled. The chain pickerel, a top predator, and several insectivorous were also collected in Cold Spring Brook Pond. Based on the data collected in this study, the species composition and taxa richness of Cold Spring Brook Pond is typical of a southern New England warm water fish community. A gross pathological examination of fish from Cold Spring Brook Pond suggests that the individuals from the population examined are healthy. No tumors, lesions, or other significant abnormalities were observed in any fish examined.

7.4.2.2 Macroinvertebrate Sampling Program. The macroinvertebrate program at Cold Spring Brook Pond was designed to provide baseline information regarding the biota associated with aquatic habitats in the vicinity of the landfill. Although some uncertainty was associated with the identified reference pond, the macroinvertebrate community data suggest that Cold Spring Brook Pond may be

un-impacted or slightly impacted relative to the reference pond. Within Cold Spring Brook Pond, sampling stations located adjacent to the landfill appear to have lower diversity and abundance of aquatic macroinvertebrates than the station located furthest from the landfill.

7.4.2.3 Aquatic Receptor Hazard Assessment. Average surface water concentrations of iron and silver exceeded the chronic criteria for these analytes. The maximum concentration of zinc exceeded the acute criterion for this analyte. The average and RME HIs were 5.0 and 4.0, respectively, suggesting that risks to aquatic life in Cold Spring Brook as a result of surface water exposures are possible, but unlikely. Concentrations of DDD, DDE, arsenic, barium, iron, lead, manganese, mercury, and nickel exceed the available sediment quality criteria and guidelines. The average exposure HQs for these analytes ranged from 1.1 (mercury) to 8.6 (DDD). REM HQs ranged from 3.4 (barium) to 26.5 (DDD). Because the USEPA sediment quality criteria for DDD and DDE may be overly conservative for use at this site, this value was adjusted to reflect more realistic site-specific values. Use of the adjusted pesticide sediment quality criteria HQ eliminates the risk from DDD for the average exposure scenario and lowers risk from DDD for RME scenarios from 26.5 to less than 2.

7.4.2.4 Semi-aquatic Receptor Hazard Assessment. For both the average exposure and RME scenarios at Cold Spring Brook Pond, no HQs were greater than 1 for any of the seven semi-aquatic receptor species evaluated. Summary HIs ranged from less than 0.01 to a high of 2.4, for the green frog. Arsenic was the primary risk contributor to the green frog, with an HQ slightly less than 1.

7.4.2.5 Supplemental Risk Assessment Summary. These findings suggest that COPCs at Cold Spring Brook Pond are not resulting in adverse ecological risk to semi-aquatic receptors at this site. Although low levels of risk to aquatic receptors were predicted, it is unlikely that these risks are present throughout the entire pond. Limited evidence exists indicating that low levels of risk to aquatic receptors may occur in the portions of the pond directly adjacent to the landfill.

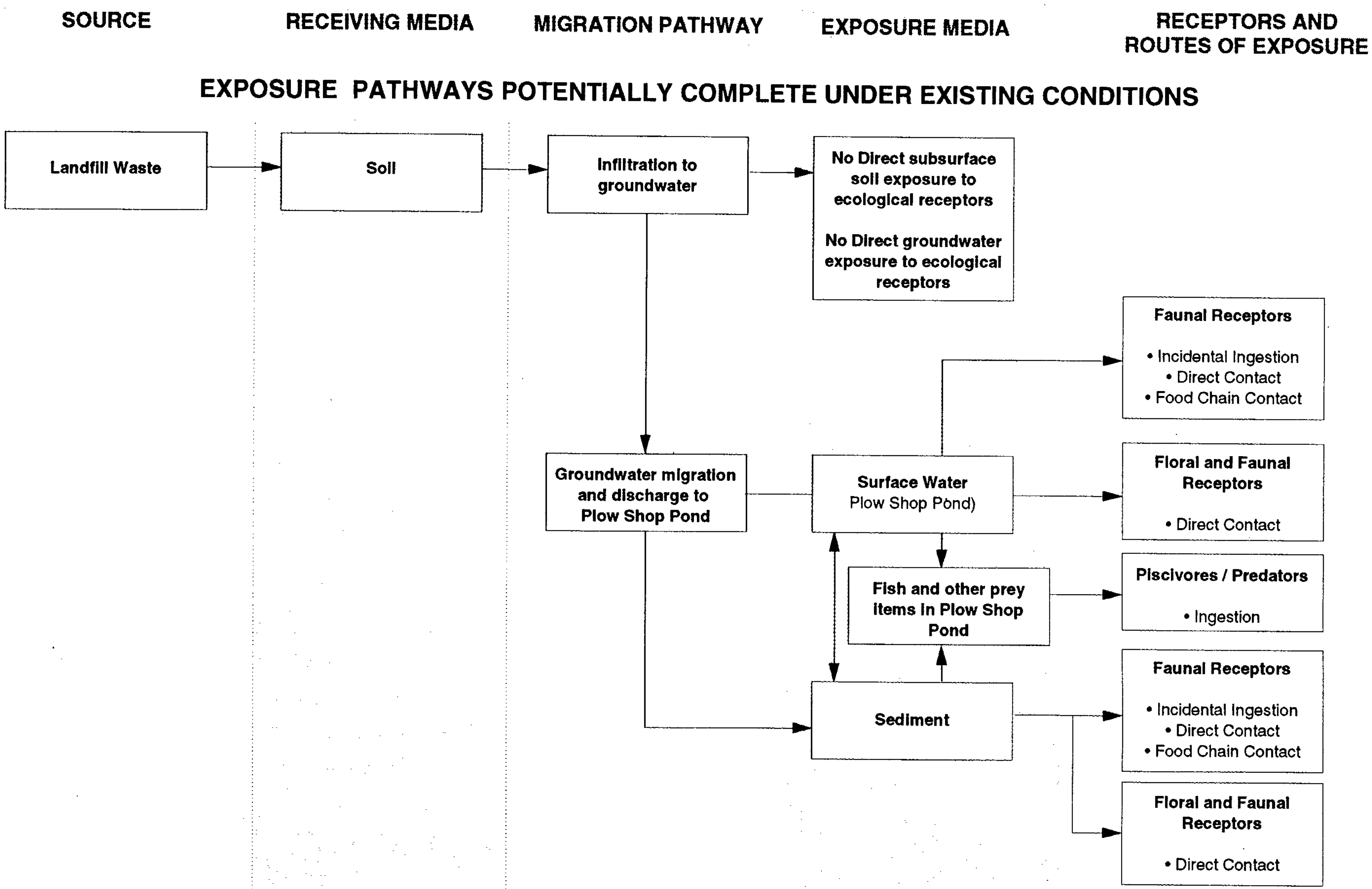


FIGURE 7-1
ECOLOGICAL SITE MODEL FOR GROUP 1A SITES
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

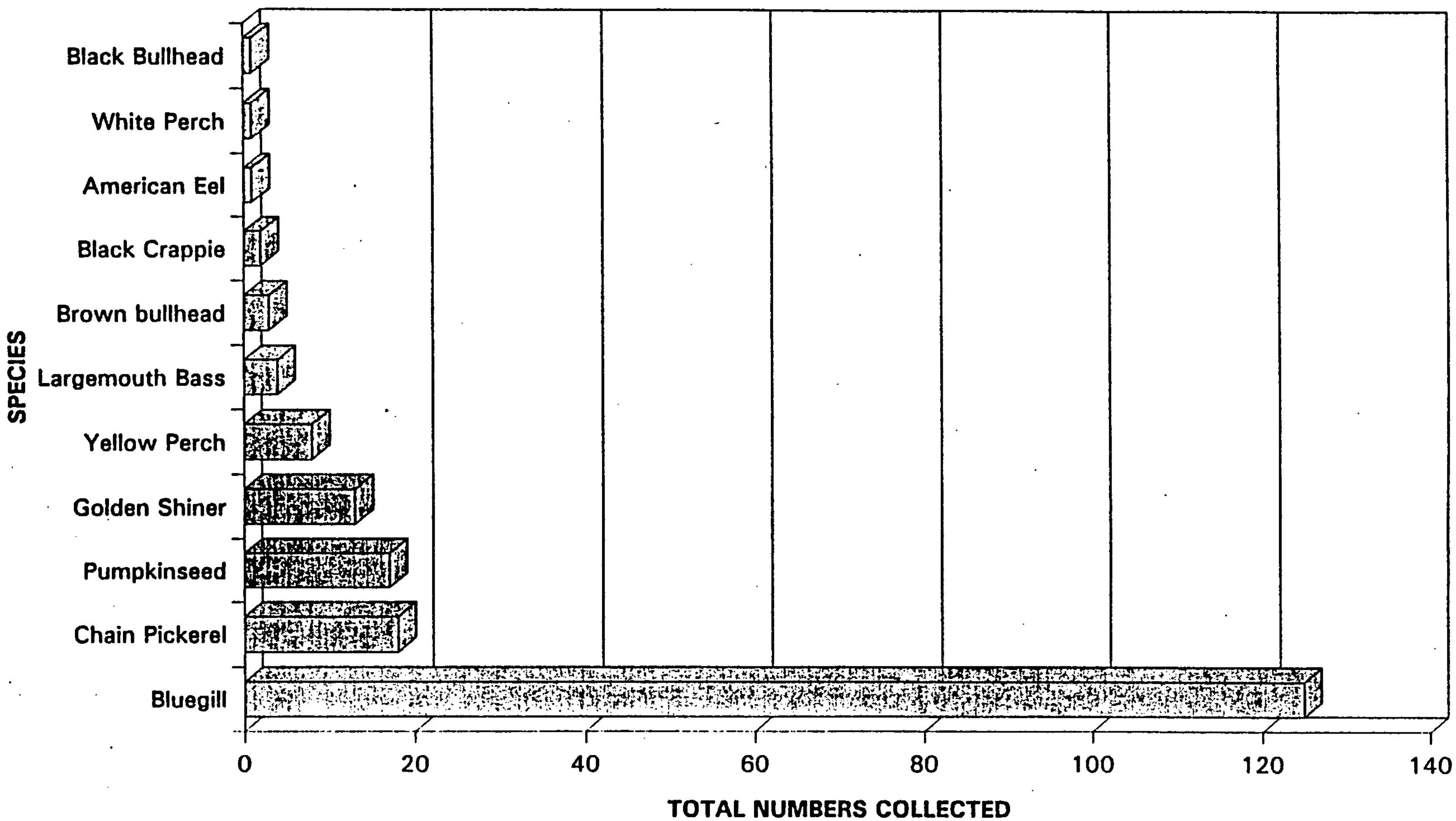


FIGURE 7-2
FISH COMMUNITY COMPOSITION PLOW SHOP POND
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

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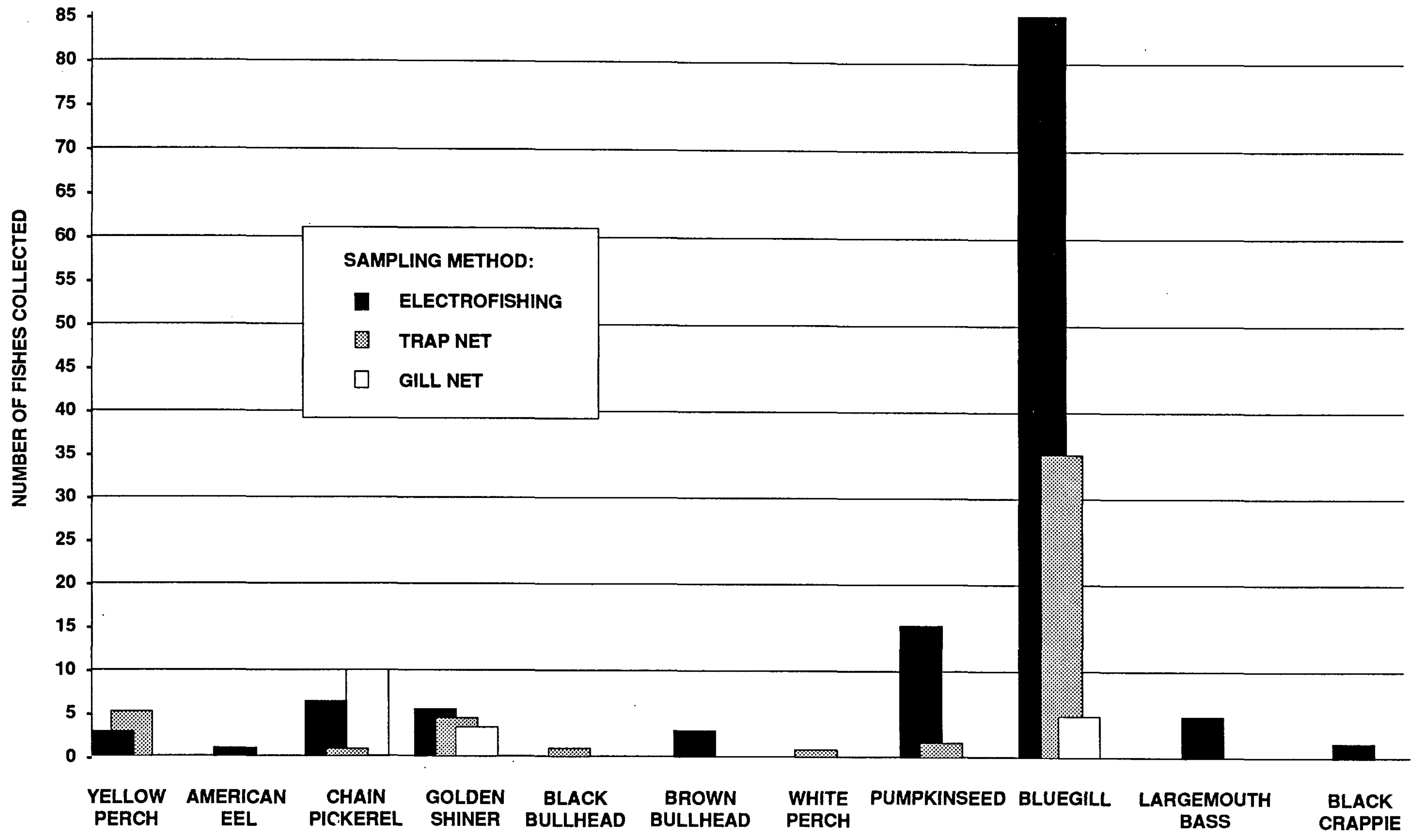

FIGURE 7-3
NUMBERS OF FISHES COLLECTED BY VARIOUS METHODS AT PLOW SHOP POND
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

7005-04

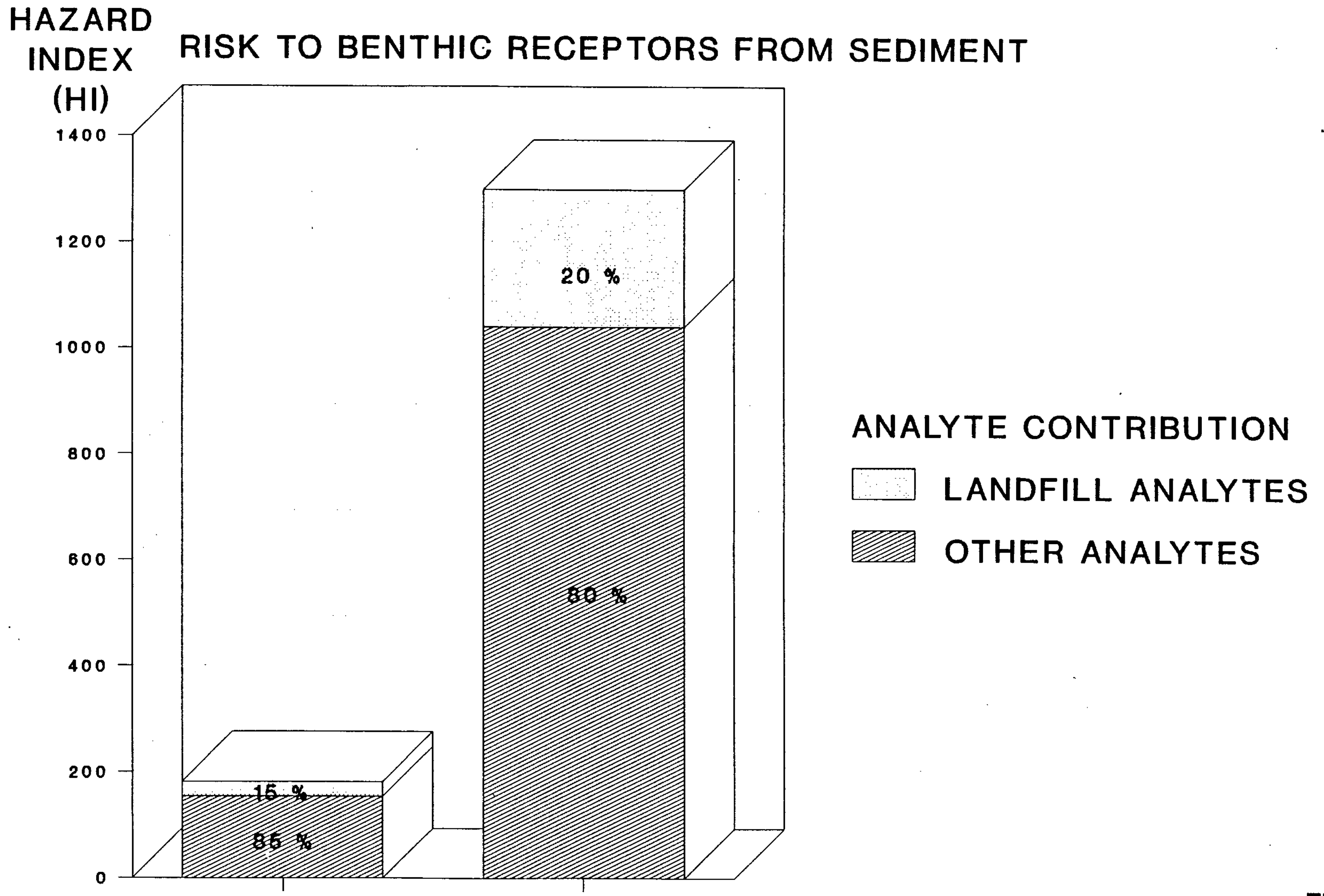

FIGURE 7-4
SUMMARY AQUATIC RECEPTOR HAZARD INDICES
PLOW SHOP POND
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

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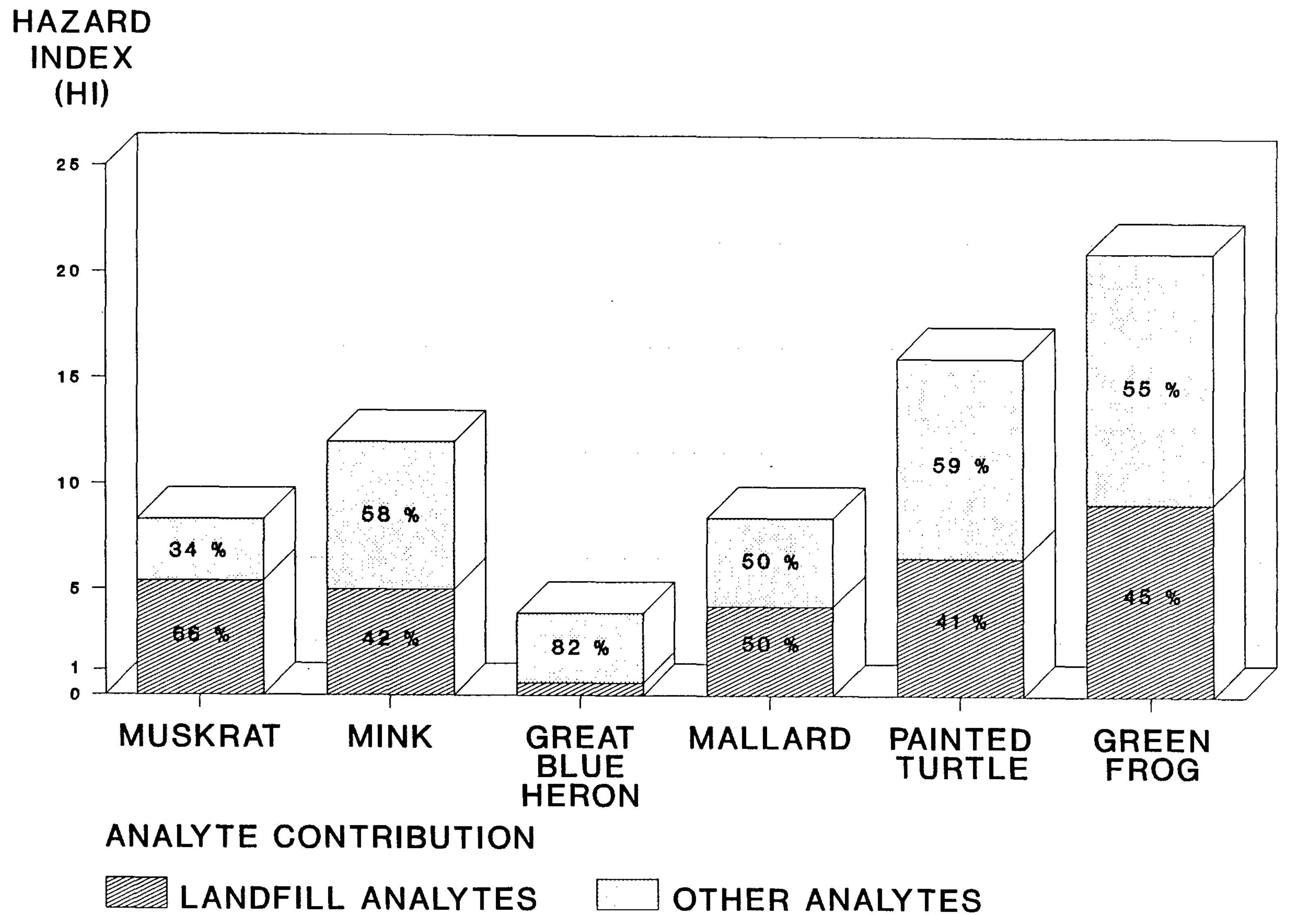

FIGURE 7-5
SUMMARY OF RME HIs FOR SEMI-TERRESTRIAL RECEPTORS
PLOW SHOP POND
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

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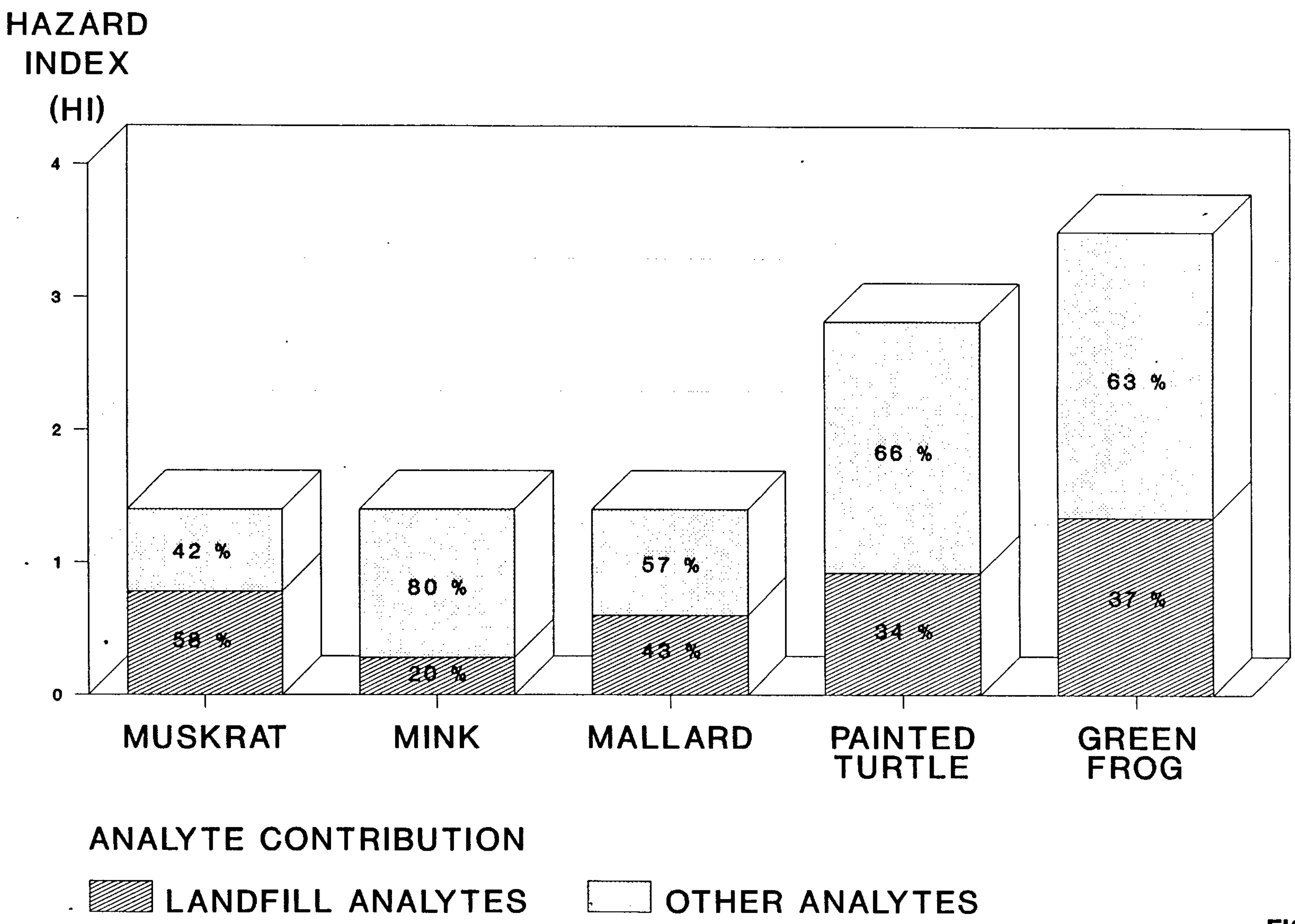

FIGURE 7-6
SUMMARY OF AVERAGE EXPOSURE
HIs FOR SEMI-TERRESTRIAL RECEPTORS
PLOW SHOP POND
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

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7005-04

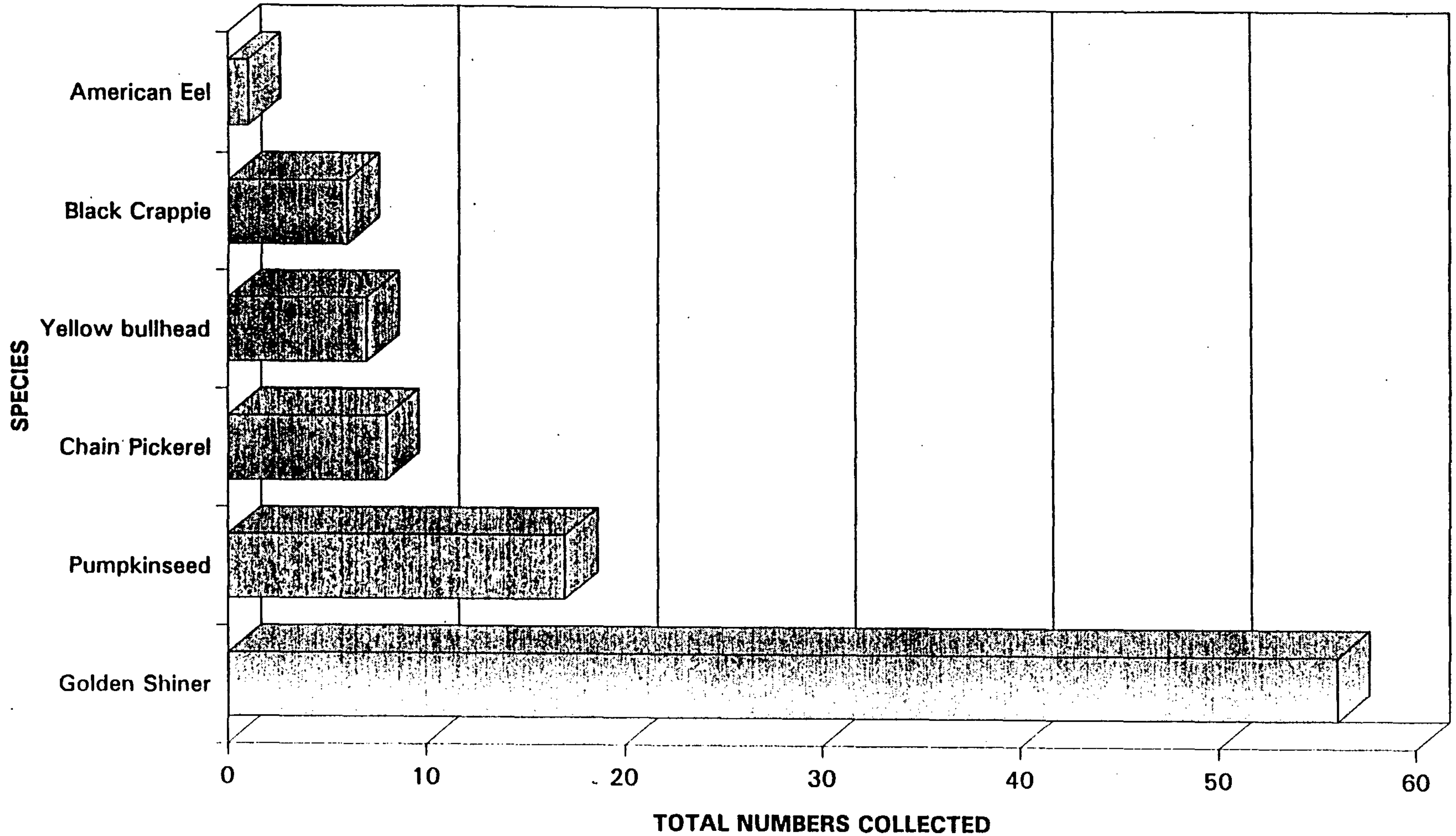

FIGURE 7-7
FISH COMMUNITY COMPOSITION
COLD SPRING BROOK POND
REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

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TABLE 7-1
SUMMARY OF RI ECOLOGICAL RISK ASSESSMENT [a]
SHEPLEY'S HILL LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ENVIRONMENTAL MEDIA	RECEPTORS	RANGE OF HAZARD INDICES	PRIMARY CONTRIBUTORS TO RISK
LANDFILL ANALYTES [b]			
Groundwater	Flora	<1 to 38	arsenic, cadmium, manganese
Sediment	Semi-aquatic Benthic invertebrates	<1 to 125 3.2 to 97	arsenic, cadmium arsenic, cadmium
OTHER ANALYTES			
Groundwater	Flora	<1 to 2.4	chromium, nickel, vanadium
Sediment	Semi-aquatic Benthic invertebrates	No analytes assessed 1.2 to 867	chromium, lead, mercury, DDE, PAHs

[a] Excerpted from Table 9-17 to 9-20 of the RI Risk Assessment (E & E, 1993).
[b] Landfill contaminants evaluated were arsenic, cadmium, manganese, and barium.

TABLE 7-2
ECOLOGICAL CONTAMINANTS OF POTENTIAL CONCERN (COPCs) [a]
PLOW SHOP POND SURFACE WATER

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CONCENTRATION		FREQUENCY OF DETECTION	COPC (Y/N)	
	AVERAGE (ug/L)	MAXIMUM (ug/L)			
LANDFILL ANALYTES [b]					
arsenic	4.32	6.96	15/15	Y	
barium	7.06	15.2	15/15	Y	
iron	473	1,100	15/15	Y	
manganese	96.5	500	15/15	Y	
nickel	15.7	44.2	8/15	Y	
OTHER ANALYTES [c]					
ORGANICS					
endrin	NC	0.008	1/15	N	[d]
chloroform	0.74	1.4	6/14 [e]	Y	
methylene chloride	7.63	8.92	14/14 [e]	N	[f]
INORGANICS					
calcium	11,900	31,000	15/15	N	[g]
chromium	2.41	4.9	1/15	Y	
copper	14.2	48.7	13/15	Y	
magnesium	2,100	2,400	15/15	N	[g]
potassium	940	1,180	15/15	N	[g]
silver	0.415	3.6	2/15	Y	
sodium	21,700	25,000	15/15	N	[g]
zinc	18.4	58.1	5/15	Y	

Notes:
[a] COPCs chosen from data presented in E&E (1993). COPCs were selected from surface water samples SW-SHL-01 through SW-SHL-15.
[b] Landfill contaminants determined in the Contaminant Assessment (Section 4).
[c] All other analytes assumed to be non-landfill contaminants.
[d] Detected only once and not above the detection limit.
[e] Volatile analysis for one of the samples (SW-SHL-11) were not conducted due to a laboratory accident.
[f] Analyte is a laboratory contaminant and therefore was excluded as a COPC (Section 4).
[g] Analyte is an essential nutrient and therefore was eliminated as a COPC.
NC = Not calculated

TABLE 7-3
ECOLOGICAL CONTAMINANTS OF POTENTIAL CONCERN (COPCs) [a]
PLOW SHOP POND SEDIMENT

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CONCENTRATION		FREQUENCY OF DETECTION	COPC (Y/N)	
	AVERAGE (ug/g)	MAXIMUM (ug/g)			
LANDFILL ANALYTES [b]					
arsenic	467	3,200	41/41	Y	
barium	108	344	38/41	Y	
nickel	23	79.3	25/41	Y	
manganese	2,639	54,800	37/41	Y	
iron	36,314	330,000	41/41	Y	
OTHER ANALYTES [c]					
ORGANICS					
acetone	0.19	0.55	9/13 [e]	N	[d]
methylene chloride	0.05	0.12	11/13 [e]	N	[d]
2-butanone	0.04	0.13	5/13 [e]	N	[d]
benzo(a)anthracene	0.22	1.1	1/13 [e]	Y	
chrysene	0.32	1.5	1/13 [e]	Y	
fluoranthene	0.5	3.4	1/13 [e]	Y	
naphthalene	0.32	1.6	1/13 [e]	Y	
phenanthrene	0.38	2.5	1/13 [e]	Y	
pyrene	0.97	4.35	3/13 [e]	Y	
DDE	0.05	1.3	6/41	Y	
DDD	0.07	1.8	4/41	Y	
DDT	0.03	0.13	1/41	Y	[f]
heptachlor	0.006	0.092	2/41	N	[d]
INORGANICS					
aluminum	7,939	24,000	41/41	Y	
beryllium	0.53	2.72	8/41	Y	
cadmium	9.8	60.2	13/41	Y	
calcium	8,074	20,100	39/41	N	[g]
cobalt	5.8	58.7	8/41	Y	
chromium	1,987	10,000	38/41	Y	
copper	39.6	132	30/41	Y	
lead	125	632	40/41	Y	
magnesium	1,629	6,900	36/41	N	[g]
mercury	18.2	130	37/41	Y	
potassium	435	2,350	17/41	N	[g]
selenium	1.95	6.6	12/41	Y	
sodium	1,113	2,870	35/41	N	[g]
vanadium	24.6	166	15/41	Y	
zinc	88.6	403	17/41	Y	

Notes:
[a] COPCs chosen from data presented in Contaminant Assessment (Section 4). COPCs were selected from sediment samples SE-SHL-01 through SE-SHL-13 and SHD-92-01 through SHD-92-28 at depths of less than 1 foot.
[b] Landfill contaminants determined in the Contaminant Assessment (Section 4).
[c] All other analytes assumed to be non-landfill contaminants.
[d] Analyte is a laboratory contaminant and was therefore eliminated as a COPC (see Section 4.0).
[e] Samples collected by ABB-ES (SHD-92-01 through SHD-92-28) were not analyzed for these analytes.
[f] Although analyte was detected in less than 5% of samples, it was retained as a COPC because of the occurrence of related chemicals with similar toxic endpoints and potentially additive effects.
[g] Analyte is an essential nutrient and therefore was eliminated as a COPC.

TABLE 7-4
SUMMARY OF COPCs IN WHOLE BODY FISH TISSUE FROM PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SPECIES	BLUEGILL (WHOLE FISH)					BULLHEAD (WHOLE FISH)				
ANALYTE	FREQUENCY OF DETECTION [a]	MINIMUM (ug/g wet weight)	MAXIMUM (ug/g wet weight)	AVERAGE [b] (ug/g wet weight)	COPC (Y/N)	FREQUENCY OF DETECTION [a]	MINIMUM (ug/g wet weight)	MAXIMUM (ug/g wet weight)	AVERAGE [b] (ug/g wet weight)	COPC (Y/N)
LANDFILL ANALYTES										
arsenic	1/5	1.3	1.3	0.33	Y	1/5	0.30	0.30	0.13	Y
barium	5/5	1.3	4.4	2.8	Y	5/5	0.33	1.3	0.79	Y
iron	5/5	42	130	80	Y	5/5	22	71	39	Y
manganese	5/5	39	95	63	Y	5/5	6.20	16	9.46	Y
OTHER ANALYTES										
PESTICIDES/PCBs										
DDE	2/5	0.021	0.029	0.013	Y	4/5	0.014	0.033	0.017	Y
DDD	ND	ND	ND	ND	Y	1/5	0.012	0.012	0.0060	Y
DDT	ND	ND	ND	ND	Y	ND	ND	ND	ND	Y
aroclor-1260	ND	ND	ND	ND	Y	ND	ND	ND	ND	Y
INORGANICS										
aluminum	5/5	1.6	4.5	2.6	Y	3/5	1.7	2.9	1.7	Y
cadmium	ND	ND	ND	ND	Y	ND	ND	ND	ND	Y
calcium	5/5	23,300	48,800	31,940	N [c]	5/5	3,250	16,500	10,048	N [c]
chromium	5/5	0.48	0.93	0.66	Y	4/5	0.25	0.99	0.42	Y
cobalt	4/5	0.10	0.16	0.11	Y	1/5	0.17	0.17	0.074	Y
copper	5/5	0.44	0.60	0.51	Y	5/5	0.43	1.3	0.76	Y
lead	1/4	0.16	0.16	0.078	Y	1/5	0.18	0.18	0.076	Y
magnesium	5/5	496	754	568	N [c]	5/5	249	459	347	N [c]
mercury	5/5	0.19	0.54	0.37	Y	5/5	0.090	0.40	0.28	Y
selenium	5/5	0.42	0.67	0.55	Y	5/5	0.24	0.31	0.27	Y
sodium	5/5	1,480	2,290	1,794	N [c]	5/5	1,080	1,410	1,206	N [c]
thallium	1/5	0.10	0.10	0.06	Y	ND	ND	ND	ND	Y
zinc	5/5	22	30	25	Y	5/5	12	22	16	Y

TABLE 7-4

SUMMARY OF COPCs IN WHOLE BODY FISH TISSUE FROM PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SPECIES	LARGEMOUTH BASS (WHOLE FISH)					ALL FISH (WHOLE FISH)				
ANALYTE	FREQUENCY OF DETECTION [a]	MINIMUM (ug/g wet weight)	MAXIMUM (ug/g wet weight)	AVERAGE [b] (ug/g wet weight)	COPC (Y/N)	FREQUENCY OF DETECTION [a]	MINIMUM (ug/g wet weight)	MAXIMUM (ug/g wet weight)	AVERAGE [b] (ug/g wet weight)	COPC (Y/N)
LANDFILL ANALYTES										
arsenic	ND	ND	ND	ND	Y	2/15	0.3	1.3	0.19	Y
barium	5/5	0.27	0.99	0.58	Y	15/15	0.27	4.4	1.4	Y
iron	5/5	11	25	16	Y	15/15	11	130	45	Y
manganese	5/5	5.1	8.8	6.3	Y	15/15	5	95	26	Y
OTHER ANALYTES										
PESTICIDES/PCBs										
DDE	5/5	0.082	0.42	0.17	Y	11/15	0.014	0.42	0.068	Y
DDD	5/5	0.021	0.11	0.046	Y	6/15	0.012	0.11	0.019	Y
DDT	1/5	0.012	0.012	0.0060	Y	1/15	0.012	0.012	0.0055	Y
aroclor-1260	5/5	0.061	0.33	0.137	Y	5/15	0.061	0.33	0.062	Y
INORGANICS										
aluminum	2/5	2.1	2.9	1.4	Y	10/15	1.6	4.5	1.9	Y
cadmium	1/5	0.090	0.090	0.044	Y	1/15	0.09	0.09	0.036	Y
calcium	5/5	12,300	35,900	20,100	N [c]	15/15	3,250	48,800	20,696	N [c]
chromium	5/5	0.32	0.65	0.43	Y	14/15	0.25	0.99	0.50	Y
cobalt	ND	ND	ND	ND	Y	5/15	0.10	0.17	0.077	Y
copper	5/5	0.44	0.90	0.58	Y	15/15	0.43	1.3	0.61	Y
lead	ND	ND	ND	ND	Y	2/14	0.16	0.18	0.067	Y
magnesium	5/5	420	671	510	N [c]	15/15	249	754	475	N [c]
mercury	5/5	0.65	2.7	1.4	Y	15/15	0.090	2.7	0.68	Y
selenium	5/5	0.26	0.54	0.4	Y	15/15	0.24	0.67	0.40	Y
sodium	5/5	1,340	2,020	1,562	N [c]	15/15	1,080	2,290	1,520	N [c]
tallium	ND	ND	ND	ND	Y	1/15	0.10	0.10	0.053	Y
zinc	5/5	13	19	16	Y	15/15	12	30	19	Y

Notes:

[a] Number of detects per total number of analyses.

[b] Average calculated using 1/2 the SQL.

[c] Essential nutrients, with the exception of iron, were eliminated as fish COPCs.

ND = Not detected.

TABLE 7-5
SUMMARY OF CHEMICALS THAT EXCEED REGIONAL (a) OR NATIONAL (b) DATA BY SPECIES
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	PLOW SHOP POND FISH [c]							
	BLUEGILL		BULLHEAD		LARGEMOUTH BASS		ALL FISH	
	Regional	National	Regional	National	Regional	National	Regional	National
LANDFILL ANALYTES								
arsenic		X		X				X
barium								
iron	X		X		X		X	
manganese	X		X		X		X	
OTHER ANALYTES								
PESTICIDES/PCBs								
aroclor-1260					X			
DDD								
DDE					X		X	
DDT								
INORGANICS								
aluminum	X		X		X		X	
cadmium						X		X
chromium	X							
cobalt								
copper				X				X
lead								
mercury		X		X	X	X	X	X
nickel								
selenium								
thallium								
zinc	X		X		X		X	
TOTAL EXCEEDANCES	7		7		9		10	

Notes:

[a] PSP average concentrations exceeding regional average concentrations (Massachusetts Division of Water Pollution Control [MADWPC], 1988a; 1988b, 1989; 1990; 1991).

[b] PSP maximum concentrations exceeding national maximum or 85th percentile concentrations (United States Fish and Wildlife Service [USFWS], 1990a; 1990b).

[c] Comparison or fish tissue concentrations to regional and national data presented in Appendix N, Tables N-6 through N-9.

TABLE 7-6
PLANT COMMUNITIES IDENTIFIED IN THE
VICINITY OF THE SHEPLEY'S HILL LANDFILL [a]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

	COVER TYPE	DOMINANT SPECIES [b]
1.	Mature White Pine Forest	White pine, Red maple, Dwarf blueberry, Bracken fern
2.	Red Pine--Scarlet Oak Early Successional Forest	Red pine, Scarlet oak, Sweetfern, Ground pine
3.	Old Field	Quaking aspen, Gray dogwood, Tartarian honeysuckle, Panic grass, Early goldenrod
4.	White Pine--Red Pine Plantation	White pine, Red pine
5.	Old Field	Quaking aspen, scarlet oak, Red pine, Tartarian honeysuckle, Fescue, Switchgrass, Slender-leaved goldenrod
6.	Sand Barren	Red pine, Gray birch, Sweetfern, Broomsedge, Orange-grass
7.	Aspen Early Successional Forest	Quaking aspen, Sweetfern
8.	Sand Barren	Sweetfern, Purple lovegrass, Broomsedge
9.	Dense Grassland	Bluegrass, Orchard grass, Path rush
10.	Wet Meadow	Nodding smartweed, Brome-like sedge, Panic grass
11.	Scarlet Oak--White Pine Forest	Scarlet oak, White pine, Red maple, Dwarf blueberry, Canada mayflower, Running cedar, Wintergreen
12.	Scarlet Oak--White Pine Regeneration Area	Scarlet oak, White pine, Red maple, Dwarf blueberry
13.	Scarlet Oak Forest	Scarlet oak, Red maple, Dwarf blueberry
14.	Burned Regeneration Area	Scarlet oak, Red maple, Black cherry, Sweet fern, Dwarf blueberry
15.	Red Maple Early Successional Forest	Red maple, Choke cherry, Canada mayflower
16.	Red Pine Plantation	Red pine
17.	White Oak--Scarlet Oak Forest	White oak, Scarlet oak, Red maple, Dwarf blueberry, Wintergreen

TABLE 7-6
PLANT COMMUNITIES IDENTIFIED IN THE
VICINITY OF THE SHEPLEY'S HILL LANDFILL [a]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

	COVER TYPE	DOMINANT SPECIES [b]
18.	Scarlet Oak Early Successional Forest	Scarlet oak, Gray birch, Red maple, Dwarf blueberry, Wintergreen
19.	Red Maple Swamp	Red maple, Nannyberry, Highbush blueberry, Marsh fern, Brome-like sedge
20.	Shoreline Wetland	Red maple, Silky dogwood, Witch hazel, Smooth alder, Marsh fern, Spotted jewelweed
21.	Floating-leaved Deep Marsh (Plow Shop Pond)	Water marigold, Sweet water lily

Notes:
[a] Source: E&E (1993)
[b] Dominant species listed only

TABLE 7-7
CHECKLIST OF FISHES COLLECTED AT PLOW SHOP POND (PSP)

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHORDATA	
OSTEICHTHYES	
ANGUILLIFORMES	
Anguillidae	
Anguilla rostrata (Lesueur)	American Eel
SALMONIFORMES	
Esocidae	
Esox niger (Lesueur)	Chain Pickerel
CYPRINIFORMES	
Cyprinidae	
Notemigonus crysoleucas (Mitchill)	Golden Shiner
SILURIFORMES	
Ictaluridae	
Ictalurus melas (Rafinesque)	Black Bullhead
Ictalurus natalis (Lesueur)	Yellow Bullhead
Ictalurus nebulosus (Lesueur)	Brown Bullhead
PERCIFORMES	
Percichthyidae	
Morone americana (Gmelin)	White Perch
Centrarchidae	
Lepomis gibbosus (Linnaeus)	Pumpkinseed
Lepomis macrochirus (Rafinesque)	Bluegill
Micropterus salmoides (Lacepede)	Largemouth Bass
Pomoxis nigromaculatus (Lesueur)	Black Crappie
Percidae	
Perca flavescens (Mitchill)	Yellow Perch

TABLE 7-8
WATER QUALITY PARAMETERS AT MACROINVERTEBRATE SAMPLING LOCATIONS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

LOCATION	pH	D.O. (ppm)	TEMPERATURE (°C)	CONDUCTIVITY (MICROSIEMENS)	DIP NET SAMPLES APPROXIMATE DEPTH (m)	DOMINANT VEGETATION	DENSITY OF VEGETATION	DEPTH OF SAMPLE	SEDIMENT DESCRIPTION
PLOW SHOP POND									
Station 1	7.32	4.4	17.2	195	0.8	Milfoil	Sparse	0.6	Fine/Coarse gravel
Station 2	7.66	7.3	18	185	0.7	Potomogeton/ Milfoil	Dense	1.4	Fine muck– Blackish
Station 3	7.39	8.3	17.9	179	0.8	Milfoil	Very Dense	1.0	Fine silt– Rusty Brown
COLD SPRING BROOK POND									
Station 1	8.15	7.8	14.8	297	0.6	Potomogeton/ Milfoil	Moderate	0.4	Organic debris
Station 2	7.49	6.7	16	256	0.8	Potomogeton	Sparse	1.2	Organic debris
Station 3	7.45	6.3	15.8	240	0.5	Potomogeton	Sparse	0.7	Silt/leaf litter–blackish
CRANBERRY POND [a]									
Station 1	6.69	5.8	14.1	43.6	0.7 – 0.9	Potomogeton/ Milfoil	Sparse	0.7	Detritus
Station 2	6.54	5.8	14.2	45.7	0.7 – 0.9	Potomogeton/ Milfoil	Sparse	0.7	Detritus
Station 3	6.68	5.9	13.7	49.6	0.7 – 0.9	Potomogeton/ Milfoil	Sparse	0.7	Detritus

Notes:

[a] Sample characterizations combined since all three stations at Cranberry Pond were similar and in close proximity (75 feet) of each other.

TABLE 7-9
SUMMARY OF SEDIMENT CHEMISTRY DATA FROM MACROINVERTEBRATE SAMPLING STATIONS
PLOW SHOP POND AND NEW CRANBERRY POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECT [a]	PLOW SHOP POND CONCENTRATION [b]		FREQUENCY OF DETECT [a]	CRANBERRY POND CONCENTRATION [b]	
		AVERAGE	MAXIMUM		AVERAGE	MAXIMUM
ORGANICS (ug/kg)						
DDT	1/3	0.046	0.13	1/3	0.03	0.07
DDD	2/3	0.155	0.28	1/3	0.14	0.295
DDE	2/3	0.04	0.075	1/3	0.059	0.13
total organic carbon	3/3	191,167	268,000	3/3	60,113	100,000
INORGANICS (ug/kg)						
aluminum	3/3	7,717	13,500	3/3	8,427	11,100
arsenic	3/3	210	310	3/3	8.1	13.8
barium	3/3	50	80	3/3	34	57
beryllium	0/3	0.25	0.25	0/3	ND	ND
cadmium	0/3	0.35	0.35	0/3	ND	ND
chromium	3/3	1,417	3,060	1/3	4.02	8.9
cobalt	3/3	28.6	51	1/3	1.1	3.1
copper	3/3	29.8	58	3/3	7.1	13.9
iron	3/3	30,767	51,300	3/3	5,465	7,140
lead	3/3	102	160	3/3	42.1	97
manganese	3/3	1,312	2,370	3/3	61.2	109
mercury	3/3	12.1	31	2/3	0.124	0.218
nickel	3/3	24.5	29.9	2/3	3.72	5.2
selenium	1/3	0.923	2.52	0/3	ND	ND
vanadium	2/3	18	30.5	3/3	14.6	24.5
zinc	3/3	105	203	3/3	31.2	55

Notes:

[a] Frequency of detection represents the number of detects per total number of samples.

[b] 1/2 the SQL was used for non-detected values for calculation of average.

ND = Not Detected.

TABLE 7-10
COMPARISON OF REFERENCE POND SEDIMENT CHEMISTRY WITH SEDIMENT QUALITY GUIDELINES AND CRITERIA

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	NEW CRANBERRY POND		USEPA [a]	NOAA [b]		NYSDEC [c]	USEPA	ONTARIO
	Average (ug/kg)	Maximum (ug/kg)	SQC (ug/g)	ER-L (ug/g)	ER-M (ug/g)	(ug/g)	REGION V [d] (ug/g)	LOWEST EFFECT LEVEL (ug/g)
ORGANICS								
phenol	0.327	0.87	NA	NA	NA	NA	NA	NA
DDD	0.14	0.295	0.05	2	20	NA	NA	0.008
DDE	0.059	0.13	0.05	2	15	NA	NA	0.005
DDT	0.03	0.07	0.05	1	7	NA	NA	0.008
INORGANICS								
aluminum	8,427	11,100	NA	NA	NA	NA	NA	NA
arsenic	8.1	13.8	NA	33	85	5	3	6
barium	34	57.4	NA	NA	NA	NA	20	NA
chromium	4.02	8	NA	80	145	26	25	26
cobalt	1.1	1.89	NA	NA	NA	NA	NA	50
copper	7.1	13.9	NA	70	390	19	25	16
iron	5,465	7,140	NA	NA	NA	24,000	17,000	20,000
lead	42.1	97	NA	35	110	27	40	31
manganese	61.2	109	NA	NA	NA	428	300	460
mercury	0.124	0.218	NA	0.15	1.3	0.11	>1	0.2
nickel	3.72	5.21	NA	30	50	22	20	16
vanadium	14.6	24.5	NA	NA	NA	NA	NA	NA
zinc	31.2	54.8	NA	120	270	85	90	120

Notes:

[a] Organic carbon normalized mean values from USEPA (1988) Interim Sediment Quality Criteria (SQC), using the average (6%) total organic carbon measured in New Cranberry Pond sediments.

[b] Effects range-low (ER-L) and Effects range-medium (ER-M) values from Long and Morgan (1990).

[c] New York State Department of Environmental Conservation ([NYSDEC], 1989).

[e] Values are Lowest Effect Level reported in Ontario Ministry of the Environment Persaud, et al. (1992).

[d] From USEPA (1977) Region V Sediment Classification System. Levels above those listed are considered moderately polluted, levels below are considered non-polluted.

[e] Lower limits were not established for cadmium and mercury- values listed for these analytes represent heavily polluted sediments.

NA = Not Available.

TABLE 7-11
CHECKLIST OF FORT DEVENS MACROINVERTEBRATES [a]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

PROTOZOA
  Sarcodinia
    Testacea
PORIFERA
  Demospongea
    Haplosclerina
      Spongillidae
        Spongillinae
          Spongilla sp.
COELENTERATA
  Hydrozoa
    Hydroida
      Hydridae
        Hydra sp.
PLATYHELMINTHES
  Acoela
  Turbellaria
    Tricladida
      Planariidae
        Phagocata sp.
NEMATODA
BRYOZOA
ANNELIDA
  Oligochaeta
    Haplotaxida
      Naididae
          Pristina sp.
          Stylaria sp.
      Tubificidae
  Hirudinea
    Rhynchobdellida
      Glossiphonidae
          Glossiphonia sp.
          Helobdella sp.
          Placobdella sp.
ARTHROPODA
  Arachnoidea
    Acariformes
      Hydrachnidae
      Arrenuridae
          Arrenurus sp.
    Hydracarina
  Crustacea
    Cladocera
      Chydoridae
          Eurycercus sp.
    Cyclopoida
    Isopoda
      Asellidae
          Caecidotea sp.
    Amphipoda
      Talitridae
          Hyalella sp.
          Hyalella azteca
    Ostracoda
  Insecta
    Collembola
      Entomobryidae
    Plecoptera
    Ephemeroptera
      Baetidae
        Baetis sp.
      Caenidae
        Caenis sp.

Heptageniidae
Epeorus sp.
Odonata
Aeschnidae
Boyeria sp.
Aeshnidae
Gomphaeschna sp.
Coenagrionidae
Enallagma sp.
Gomphidae
Gomphus sp.
Lestidae
Lestes sp.
Libellulidae
Libellula sp.
Sympetrum sp.
Tramea sp.
Megaloptera
Sialidae
Sialis sp.
Trichoptera
Hydroptilidae
Hydroptilinae
Leptoceridae
Leptocerus sp.
Nectopsyche sp.
Oecetis sp.
Triaenodes sp.
Limnephilidae
Limnephilus sp.
Polycentropodidae
Polycentropus sp.
Lepidoptera
Noctuidae
Pyralidae
Parapoynx sp.
Coleoptera
Chrysomelidae
Donacia sp.
Dytiscidae
Elmidae
Haliplidae
Haliplus sp.
Diptera
Ceratopogonidae
Sphaeromias sp.
Culicoidinae
Bezzia sp.
Palpomyia sp.
Palpomyia tibialis
Chaoboridae
Chaoborus sp.
Chaoborus punctipennis
Chironomidae
Tanypodinae
Ablabesmyia sp.
Natarsia sp.
Procladius sp.
Tanypus sp.
Orthocladiinae
Cricotopus sp.
Omisus sp.
Parorthocladius sp.
Chironominae

TABLE 7–11
CHECKLIST OF FORT DEVENS MACROINVERTEBRATES [a]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

Chironomus sp.
Chironomus halaphilus grp.
Dicrotendipes sp.
Hyporhygma sp.
Lauterborniella sp.
Microtendipes sp.
Parachironomus sp.
Polypedilum sp.
Tanytarsus sp.
Athericidae
Atherix sp.
Tabanidae
Chrysops sp.
Hemiptera
Corixidae
Corixinae
Trichocorixa sp.
Hebridae
Hebrus sp.
Mesoveliidae
Mesovelia sp.
Pleidae
Plea sp.
Saldidae
MOLLUSCA
Gastropoda
Basommatophora
Lymnaeidae
Lymnaea sp.
Physidae
Physa sp.
Planorbidae
Gyraulus sp.
Helisoma sp.
Menetus sp.
Pelecypoda
Prionodesmacea
Sphaeriidae
Pisidium sp.

Notes:
[a] Samples collected September 24 and 25, 1992 from Plow Shop Pond, Cold Spring Brook Pond, and New Cranberry Pond.

TABLE 7-12
CHECKLIST OF GROVE POND MACROINVERTEBRATES [a]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANNELIDA
- Hirudinea
  - Indeterminate
- Oligochaeta
  - Haplotaxida
    - Tubificidae
      - Indeterminate

ARTHROPODA
- Crustacea
  - Amphipoda
    - Talitridae
      - *Hyalella azteca*
  - Cladocera
    - Chydoridae
      - Indeterminate
- Insecta
  - Ephemeroptera
    - Caenidae
      - *Caenis Caeısp.*
  - Odonata
    - Coenagrionidae
      - *Enallagma sp.*
      - *Argia sp.*
      - Indeterminate
    - Libellulidae
      - *Leucorrhinia sp.*
    - Coleoptera
      - Chrysomelidae
        - *Donacia sp.*
        - Indeterminate
      - Haliplidae
        - *Haliplus sp.*
    - Diptera
      - Chaoboridae
        - *Chaoborus sp.*
      - Chironomidae
        - Tanypodinae
          - *Clanotanypus sp..*
          - *Procladius sp.*
          - Indeterminate
        - Chironominae
          - *Phaenopsectra sp.*
          - *Polypedilum sp.*
          - Indeterminate
          - *Chironomus sp.*
          - *Tanytarsus sp.*
          - *Pseudochironomus sp.*
          - *Parachironomus sp.*
          - *Xenochironomus sp.*
          - *Microtendipes sp.*
          - *Cryptochironomus sp.*
      - Athericidae
        - *Atherix sp.*
      - Ceratopogonidae
        - *Sphaeromias sp.*
        - Culicoidinae
          - *Bezzia sp.*
      - Hemiptera

TABLE 7-12
CHECKLIST OF GROVE POND MACROINVERTEBRATES [a]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

- Corixidae
  - Indeterminate
  - Corixinae
    - *Trichocorixa sp.*
- Trichoptera
  - Hydroptilidae
    - Hydroptilinae

Note:
[a] Samples collected by MADEP at Grove Pond, September, 1992, as described in the supplemental Risk Assessment.

Table 7-13
Primary Routes of Exposure to Sediment and Fish Tissue
Plow Shop Pond

Remedial Investigation Addendum Report
Feasibility Study for Group 1A Sites
Fort Devens, MA

Medium	Route of Exposure	Populations Exposed
Fish Tissue	Ingestion of contaminated tissue	Amphibians, reptiles, birds, and mammals
	Indirect exposures associated with the consumption of contaminated dietary items	Reptiles, birds, and mammals
Sediment	Ingestion of contaminated sediment	Invertebrates, fish, amphibians, reptiles, and mammals
	Dermal contact with contaminated sediments	Invertebrates, fish, amphibians, reptiles, and mammals
	Assimilation via respiratory gill epithelium	Invertebrates, fish, and amphibians
	Root uptake	Vascular plants
	Indirect exposures associated with the consumption of contaminated dietary items [1]	Fish, amphibians, reptiles, waterfowl, and mammals
Surface Water	Ingestion of contaminated surface water	Invertebrates, fish, amphibians, reptiles, and mammals
	Dermal contact with contaminated surface water	Invertebrates, fish, amphibians, reptiles, and mammals
	Assimilation via respiratory gill epithelium	Invertebrates, fish, and amphibians
	Root uptake	Vascular plants
	Indirect exposures associated with the consumption of contaminated dietary items [1]	Fish, amphibians, reptiles, waterfowl, and mammals

Note:

1. Indirect exposure is intended to represent food chain exposure to environmental contaminants at Plow Shop Pond.

TABLE 7-14
SURFACE WATER REFERENCE TOXICITY VALUES
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	USEPA AMBIENT WATER QUALITY CRITERIA (f) (µg/l)		TOXICITY VALUES (g) (µg/l)	
	Chronic	Acute	Chronic	Acute
LANDFILL ANALYTES				
arsenic (a)	190	360		
barium (b)	NA	NA	200	2,000
iron	1,000	10,000		
nickel (c)	65	580		
manganese (d)	NA	NA	1,000	10,000
OTHER ANALYTES				
ORGANICS				
chloroform (e)	NA	NA	248	3,580
INORGANICS				
chromium (c)	88	740		
copper (c)	4.8	6.6		
silver	0.12	0.92		
zinc (c)	44	48		

Notes:

[a] Values shown are for trivalent arsenic (AsIII).

[b] Lowest end of range of concentrations lethal to aquatic invertebrates and fish (NAS 1972) with a safety factor of 0.2 applied.

[c] AWQC are dependent upon water hardness; the average Plow Shop Pond hardness (35 mg/l $CaCO_3$) was used.

[d] Value reported by McKee and Wolf (1963 in USEPA, 1976) and Davies and Goettl (in Lewis et al., 1979) which is considered protective of freshwater species.

[e] Lowest of range of concentrations associated with acute or chronic effects obtained from an AQUIRE search (1990). Acute value is a 96-hr LC_{50} for bluegill sunfish reported by Anderson and Lusty (1980; in AQUIRE 1990). Chronic value is a 28-day embryo-larval LC50 for rainbow trout reported by Black and Birge (1980, in AQUIRE, 1990) with a safety factor of 0.2 applied.

[f] USEPA (1986)

[g] Other reference toxicity values are presented only for those chemicals for which AWQC are not available.

TABLE 7–15
SEDIMENT QUALITY CRITERIA AND GUIDELINES
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUPS 1A SITES
FORT DEVENS, MA

ANALYTE	USEPA [a] SQC ($\mu g/g$)	NOAA [b] ER–L ($\mu g/g$)	NOAA [b] ER–M ($\mu g/g$)	NYSDEC [c] ($\mu g/g$)	ONTARIO LOWEST EFFECT LEVEL ($\mu g/g$)	USEPA REGION V [e] ($\mu g/g$)
LANDFILL ANALYTES						
arsenic	NA	33	85	5	6	3
barium	NA	NA	NA	NA	NA	20
iron	NA	NA	NA	24,000	20,000	17,000
nickel	NA	30	50	22	16	20
manganese	NA	NA	NA	428	460	300
OTHER ANALYTES						
ORGANICS						
benzo(a)anthracene	431.9	0.23	1.6	NA	NA	NA
chrysene	348.7[f]	0.4	2.8	NA	NA	NA
fluoranthene	617.6	0.6	3.6	NA	NA	NA
naphthalene	348.7[f]	0.34	2.1	NA	NA	NA
phenanthrene	45.6	0.225	1.38	45.6	NA	NA
pyrene	430	0.35	2.2	NA	NA	NA
DDD	0.272 [g]	0.002	0.02	0.272	0.008	NA
DDE	0.272 [g]	0.002	0.15	0.272	0.005	NA
DDT	0.272	0.001	0.007	0.272	0.008	NA
INORGANICS						
aluminum	NA	NA	NA	NA	NA	NA
beryllium	NA	NA	NA	NA	NA	NA
cadmium	NA	5	9	0.8	0.6	6
cobalt	NA	NA	NA	NA	50	NA
chromium	NA	80	145	26	26	25
copper	NA	70	390	19	16	25
lead	NA	35	110	27	31	40
mercury	NA	0.15	1.3	0.11	0.2	1
selenium	NA	NA	NA	NA	NA	NA
vanadium	NA	NA	NA	NA	NA	NA
zinc	NA	120	270	85	120	90

Notes:
[a] Organic carbon–normalized mean values from USEPA (1988) Interim Sediment Quality Criteria (SQC), using the average (32.8%) total organic carbon measured in Plow Shop Pond sediments.
[b] Effects Range–Low (ER–L) and Effects Range–Medium (ER–M) values from Long and Morgan (1990).
[c] New York State Department of Environmental Conservation ([NYSDEC], 1989. Organics were organic carbon normalized using 32.8% total organic carbon.
[d] Values are Lowest Effect Level reported in Persaud, et al. (1992).
[e] From USEPA (1977) Region V Sediment Classification System. Levels above those listed are considered moderately polluted, levels below are considered non–polluted. Lower limits were not established for cadmium and mercury. Values listed for these analytes represent heavily polluted sediments.
[f] Guideline for benzo(a)pyrene.
[g] Guideline for DDT.
NA = Not Available.

TABLE 7-16
SUMMARY OF EXTERNAL EXAMINATIONS OF SELECTED FISH IN PLOW SHOP POND [A]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SPECIES	NUMBER EXAMINED	FRAYED FINS	TUMORS/ LESIONS	OTHER	REMARKS (FOR OTHER)
Bluegill	114	1	0	2	1-missing 1/2 gill; 1-generally poor overall
Golden Shiner	13	1	0	1	1-deformed tail
Yellow Perch	8	1	0	0	
Largemouth Bass	8	1	0	0	
Chain Pickerel	18	1	0	3	1-very thin, poor overall, cataract in left eye; 1-right lower jaw deformed; 1-frayed opercle

Note:

[a] Fish captured in nets when the fin fraying was likely caused by the nets were not included in this tabulation.

TABLE 7-17
AQUATIC RECEPTOR RISK CHARACTERIZATION
PLOW SHOP POND: SURFACE WATER

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	AVERAGE EXPOSURE			REASONABLE MAXIMUM EXPOSURE (RME)		
	Average (ug/l)	Chronic Criteria and Toxicity Values [a] (ug/l)	Hazard Quotient [b] (unitless)	Maximum (ug/l)	Acute Criteria and Toxicity Values [a] (ug/l)	Hazard Quotient [b] (unitless)
LANDFILL ANALYTES						
arsenic	4.32	190	2.27E-02	6.96	360	1.93E-02
barium	7.06	200	3.53E-02	15.2	2,000	7.60E-03
iron	473.0	1,000	4.73E-01	1,100	10,000	1.10E-01
manganese	96.5	1,000	9.65E-02	500	10,000	5.00E-02
nickel	15.7	65	2.42E-01	44.2	580	7.62E-02
	LANDFILL AVERAGE HAZARD INDEX [c]		8.69E-01	LANDFILL RME HAZARD INDEX [c]		2.63E-01
OTHER ANALYTES						
ORGANICS						
chloroform	0.740	248	2.98E-03	1.41	3,580	3.94E-04
INORGANICS						
chromium	2.41	88	2.74E-02	4.9	740	6.62E-03
copper	14.2	4.8	2.96E+00	48.7	6.6	7.38E+00
silver	0.415	0.12	3.46E+00	3.6	0.92	3.91E+00
zinc	18.4	44	4.18E-01	58.1	48	1.21E+00
	OTHER ANALYTE AVERAGE HAZARD INDEX [c]		6.87E+00	OTHER ANALYTE RME HAZARD INDEX [c]		1.25E+01
	TOTAL AVERAGE HAZARD INDEX [c]		7.73E+00	TOTAL RME HAZARD INDEX [c]		1.28E+01

Notes:
[a] Criteria from Table 7-14, chosen as described in Section 7.1.3.4.
[b] Hazard Quotient is calculated by dividing analyte concentration by surface water criterion/toxicity value.
[c] Hazard Index is the sum of all hazard quotients.
NA = Not Available
Shaded values represent a hazard index greater than one

TABLE 7-18
AQUATIC RECEPTOR RISK CHARACTERIZATION
PLOW SHOP POND: SEDIMENTS

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	AVERAGE EXPOSURE			REASONABLE MAXIMUM EXPOSURE (RME)		
	Average (ug/g)	Sediment Quality Criteria and Guideline Values [a] (ug/g)	Hazard Quotient [b] (unitless)	Maximum (ug/g)	Sediment Quality Criteria and Guideline Values [a] (ug/g)	Hazard Quotient [b] (unitless)
LANDFILL CONTAMINANTS						
arsenic	467	33	1.42E+01	3,200	33	9.70E+01
barium	108	20	5.40E+00	344	20	1.72E+01
nickel	23	30	7.67E-01	79.3	30	2.64E+00
manganese	2,639	428	6.17E+00	54,800	428	1.28E+02
iron	36,314	24,000	1.51E+00	330,000	24,000	1.38E+01
	LANDFILL HAZARD INDEX [c]		**2.80E+01**	**LANDFILL HAZARD INDEX [c]**		**2.59E+02**
OTHER ANALYTES						
ORGANICS						
benzo(a)anthracene	0.22	431.9	5.09E-04	1.1	431.9	2.55E-03
chrysene	0.32	348.7	9.18E-04	1.5	348.7	4.30E-03
fluoranthene	0.5	617.6	8.10E-04	3.4	617.6	5.51E-03
naphthalene	0.32	348.7	9.18E-04	1.6	348.7	4.59E-03
phenanthrene	0.38	45.6	8.33E-03	2.5	45.6	5.48E-02
pyrene	0.97	430	2.26E-03	4.4	430	1.01E-02
DDE	0.05	0.272	1.84E-01	1.3	0.272	4.78E+00
DDD	0.07	0.272	2.57E-01	1.8	0.272	6.62E+00
DDT	0.03	0.272	1.10E-01	0.13	0.272	4.78E-01
INORGANICS						
aluminum	7,939	NA	NA	24,000	NA	NA
beryllium	0.53	NA	NA	2.72	NA	NA
cadmium	9.8	5	1.96E+00	60.2	5	1.20E+01
cobalt	5.8	50	1.16E-01	58.7	50	1.17E+00
chromium	1,987	80	2.48E+01	10,000	80	1.25E+02
copper	39.7	70	5.67E-01	132	70	1.89E+00
lead	125	35	3.57E+00	632	35	1.81E+01
mercury	18.2	0.15	1.21E+02	130	0.15	8.67E+02
selenium	1.95	NA	NA	6.6	NA	NA
vanadium	24.6	NA	NA	166	NA	NA
zinc	88.6	120	7.38E-01	403	120	3.36E+00
	OTHER PARAMETER AVERAGE HAZARD INDEX [c]		**1.54E+02**	**OTHER PARAMETER RME HAZARD INDEX [c]**		**1.04E+03**
	TOTAL AVERAGE HAZARD INDEX [c]		**1.82E+02**	**TOTAL RME HAZARD INDEX [c]**		**1.30E+03**

Notes:
[a] Criteria and guideline values from Table 7-15, chosen as described in Section 7.1.3.4.
[b] Hazard Quotient is calculated by dividing analyte concentration by sediment quality criterion/guidance value.
[c] Hazard Index is the sum of all hazard quotients.
NA = Not Available
Shaded values represent a hazard index greater than one

TABLE 7-19
SUMMARY OF ECOLOGICAL RISK ASSESSMENT FOR SEMI-AQUATIC RECEPTORS
PLOW SHOP POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

INDICATOR SPECIES	HAZARD INDICES		PRIMARY CONTRIBUTORS TO RISK [c]
	RME [a]	AVERAGE [b]	
		Landfill Analytes [d]	
Mallard Duck	4.2E+00	6.0E-01	arsenic
Great Blue Heron	5.8E-01	7.8E-02	
Osprey	2.7E-03	3.3E-04	
Green Frog	9.1E+00	1.3E+00	arsenic
Painted Turtle	6.5E+00	9.2E-01	arsenic
Muskrat	5.4E+00	7.8E-01	arsenic
Mink	5.0E+00	2.8E-01	manganese
Raccoon	1.0E-01	5.7E-03	
		All Analytes	
Mallard Duck	8.4E+00	1.4E+00	arsenic, Chromium
Great Blue Heron	3.3E+00	5.4E-01	chromium, Mercury
Osprey	6.8E-02	8.9E-03	
Green Frog	2.1E+01	3.5E+00	Arsenic, Chromium
Painted Turtle	1.6E+01	2.8E+00	Arsenic, Chromium
Muskrat	8.3E+00	1.4E+00	Arsenic
Mink	1.2E+01	1.4E+00	Mercury, Manganese
Raccoon	2.1E-01	2.4E-02	

Notes:

[a] HIs derived under reasonable maximum exposure assumptions (see Section 7.1.3.5); calculations presented in Tables R-3 and R-4 for landfill analytes and in R-7 and R-8 for all analytes respectively in Appendix R.
[b] HIs derived under average exposure assumptions (see Section 7.1.3.5); calculations presented in Tables R-1 and R-2 for landfill analytes and in R-5 and R-6 for all analytes respectively in Appendix R.
[c] Analytes with calculated HQs in excess of 1 for either the RME or average exposure scenarios.
[d] HIs derived based on exposure to the landfill related CPCs (i.e., arsenic, barium, manganese, and nickel).

TABLE 7-20
SUMMARY OF RI ECOLOGICAL RISK ASSESSMENT [a]
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ENVIRONMENTAL MEDIA	RECEPTORS	RANGE OF HAZARD INDICES	PRIMARY CONTRIBUTORS TO RISK
LANDFILL CONTAMINANT			
Sediment			
	Semi-aquatic	<1 to 7.8	arsenic, DDD, DDE
	Benthic Invertebrates	<1 to 645	arsenic, DDD, DDE, PAHs
OTHER PARAMETERS			
Sediment			
	Semi-aquatic	No analytes assessed	
	Benthic Invertebrates	<1 to 9.9	lead, mercury, zinc

Note:
[a] Excerpted from Table 9-24 and Table 9-36 through 9-39 of the RI Risk Assessment, December 1992 (E & E. 1993).

TABLE 7-21
ECOLOGICAL CONTAMINANTS OF POTENTIAL CONCERN (COPCs) [a]
COLD SPRING BROOK POND SURFACE WATER

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CONCENTRATION		FREQUENCY OF DETECTION	COPC (Y/N)	
	AVERAGE (ug/l)	MAXIMUM (ug/l)			
ORGANICS					
methylene chloride	7.58	9.8	10/10	N	[b]
INORGANICS					
arsenic	7.7	17.7	10/10	Y	
barium	10.7	13.4	10/10	Y	
calcium	24,600	28,000	10/10	N	[c]
chromium	2.70	4.76	2/10	Y	
copper	4.4	6.75	7/10	Y	
iron	1,560	3,200	10/10	Y	
magnesium	3,070	3,300	10/10	N	[c]
manganese	151	400	10/10	Y	
potassium	1,679	2,010	10/10	N	[c]
silver	0.2	0.708	1/10	Y	
zinc	21.8	86.3	3/10	Y	

Notes:
[a] COPCs chosen from data presented in E&E (1993). COPCs were selected from surface water samples SW-CSB-01 through SW-CSB-10.
[b] Analyte is a laboratory contaminant and was therefore eliminated as a COPC (Section 4.0)
[c] Analyte is an essential nutrient and was therefore elimated as a COPC.

TABLE 7-22
ECOLOGICAL CONTAMINANTS OF POTENTIAL CONCERN (COPCs) [a]
COLD SPRING BROOK POND SEDIMENT

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	CONCENTRATION AVERAGE (ug/g)	CONCENTRATION MAXIMUM (ug/g)	FREQUENCY OF DETECTION	COPC (Y/N)	
ORGANICS					
acetone	0.02	0.17	8/9 [b]	N	[c]
methylene chloride	0.01	0.061	9/9 [b]	N	[c]
2-butanone	0.003	0.025	1/9 [b]	N	[c]
ancenapthene	0.18	0.87	1/25	N	[d]
acenapthylene	0.26	3	1/25	N	[d]
anthracene	0.27	3	1/25	Y	[e]
benzo(a)anthracene	0.51	4	2/25	Y	
benzo(a)pyrene	1.1	6	2/25	Y	
benzo(b)fluoranthene	0.64	5	2/25	Y	
benzo(g,h,i)perylene	0.48	1	1/25	N	[d]
benzo(k)fluoranthene	0.9	10	2/25	Y	
bis(2-ethylhexyl)phthalate	1.4	2	1/25	Y	[e]
chrysene	0.63	8	2/25	Y	
dibenzofuran	0.15	0.61	2/25	Y	
fluoranthene	1.6	10	11/25	Y	
fluorene	0.16	0.2	1/25	N	[d]
indeno(1,2,3-cd)pyrene	0.56	2	1/25	N	[d]
naphthalene	0.14	0.25	1/25	N	[d]
phenanthrene	0.77	6	3/25	Y	
pyrene	2.2	20	5/25	Y	
DDD	0.5	6.2	16/25	Y	
DDE	0.09	0.72	14/25	Y	
DDT	0.64	15	6/25	Y	
INORGANICS					
aluminum	6,108	17,000	25/25	Y	
arsenic	78	390	25/25	Y	
barium	36.8	115	24/25	Y	
beryllium	0.19	0.41	2/25	Y	
calcium	8,582	41,600	20/25	N	[f]
cobalt	3.38	19.6	8/25	Y	
chromium	15.1	64.8	15/25	Y	
copper	8.5	42.9	16/25	Y	
iron	15,232	45,000	25/25	Y	
potassium	758	3,580	22/25	N	[f]
lead	69.5	570	25/25	Y	
magnesium	2,246	7,160	25/25	N	[f]
manganese	634	3,000	25/25	Y	
mercury	0.077	0.72	7/25	Y	
nickel	10.8	54.3	16/25	Y	
selenium	1.96	5.77	5/25	Y	
silver	0.65	6.35	4/25	Y	
sodium	452	1,860	20/25	N	[f]
vanadium	12.1	48.6	18/25	Y	
zinc	82.3	690	17/25	Y	

Notes:

[a] COPCs chosen from data presented in Contaminant Assessment (Section 4). COPCs were selected from sediment samples SE-CSB-01 through SE-CSB-09 and CSD-92-01 through CSD-92-16, at depths of less than one foot.

[b] Samples collected by ABB-ES (CSD-92-01 through CSD-92-16) were not analyzed for these analytes

[c] Analyte is a laboratory contaminant and was therefore eliminated as a COPC (Section 4)

[d] Analyte was detected in less than 5% of samples and therefore was eliminated as a COPC.

[e] Although analyte was detected in less than 5% of samples, it was retained as a COPC because reported concentrations are at or near sediment quality criteria/guideline concentration.

[f] Analyte is an essential nutrient and therefore was eliminated as a COPC.

TABLE 7-23

SUMMARY OF CONTAMINANTS OF CONCERN IN WHOLE BODY FISH TISSUE FROM COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SPECIES	PUMPKINSEED (WHOLE FISH)					PICKEREL (WHOLE FISH)				
PARAMETER	FREQUENCY OF DETECTION (a)	MINIMUM (ug/g wet weight)	MAXIMUM (ug/g wet weight)	AVERAGE (b) (ug/g wet weight)	COPC (Y/N)	FREQUENCY OF DETECTION (a)	MINIMUM (ug/g wet weight)	MAXIMUM (ug/g wet weight)	AVERAGE (b) (ug/g wet weight)	COPC (Y/N)
PESTICIDES/PCBs										
DDE	3/3	0.022	0.17	0.083	Y	3/3	0.026	0.15	0.079	Y
DDD	3/3	0.019	0.23	0.115	Y	3/3	0.038	0.16	0.088	Y
aroclor-1254	ND	ND	ND	ND	Y	ND	ND	ND	ND	Y
INORGANICS										
arsenic	1/3	0.27	0.27	0.15	Y	ND	ND	ND	ND	Y
barium	3/3	0.24	0.64	0.47	Y	2/3	0.39	0.52	0.34	Y
calcium	3/3	8,510	15,500	13,137	N[c]	3/3	4,940	10,600	7,827	N[c]
chromium	3/3	0.23	0.33	0.30	Y	2/3	0.23	0.27	0.20	Y
cobalt	2/3	0.11	0.20	0.12	Y	ND	ND	ND	ND	Y
copper	3/3	0.37	0.41	0.39	Y	3/3	0.46	0.67	0.58	Y
iron	3/3	25	42	33	Y	3/3	12	15	13	Y
magnesium	3/3	325	464	417	N[c]	3/3	350	426	388	N[c]
manganese	3/3	7.6	12	10	Y	3/3	6	14	10	Y
mercury	3/3	0.080	0.24	0.16	Y	3/3	0.23	0.47	0.36	Y
selenium	2/3	0.24	0.45	0.25	Y	2/3	0.17	0.25	0.16	Y
sodium	3/3	1,060	1,280	1,173	N[c]	3/3	912	1,170	1,044	N[c]
zinc	3/3	17	24	21	Y	3/3	37	51	43	Y

TABLE 7–23
SUMMARY OF CONTAMINANTS OF CONCERN IN WHOLE BODY FISH TISSUE FROM COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SPECIES	BULLHEAD (WHOLE FISH)					ALL FISH (WHOLE FISH)				
PARAMETER	FREQUENCY OF DETECTION (a)	MINIMUM (ug/g wet weight)	MAXIMUM (ug/g wet weight)	AVERAGE (b) (ug/g wet weight)	COPC (Y/N)	FREQUENCY OF DETECTION (a)	MINIMUM (ug/g wet weight)	MAXIMUM (ug/g wet weight)	AVERAGE (b) (ug/g wet weight)	COPC (Y/N)
PESTICIDES/PCBs										
DDE	3/3	0.031	0.15	0.085	Y	9/9	0.022	0.17	0.082	Y
DDD	3/3	0.034	0.34	0.17	Y	9/9	0.019	0.34	0.12	Y
aroclor-1254	1/3	0.052	0.052	0.034	Y	1/9	0.052	0.052	0.028	Y
INORGANICS										
arsenic	ND	ND	ND	ND	Y	1/9	0.27	0.27	0.10	Y
barium	2/3	0.24	0.41	0.26	Y	7/9	0.24	0.64	0.36	Y
calcium	3/3	7,820	19,100	11,807	N [c]	9/9	4,940	19,100	10,923	N [c]
chromium	2/3	0.21	0.43	0.25	Y	7/9	0.21	0.43	0.25	Y
cobalt	2/3	0.12	0.16	0.11	Y	4/9	0.11	0.20	0.093	Y
copper	3/3	0.39	0.68	0.55	Y	9/9	0.37	0.68	0.51	Y
iron	3/3	21	36	29	Y	9/9	12	42	25	Y
magnesium	3/3	305	513	378	N [c]	9/9	305	513	394	N [c]
manganese	3/3	5.1	10	7.1	Y	9/9	5.1	14	8.9	Y
mercury	3/3	0.090	0.14	0.12	Y	9/9	0.08	0.47	0.21	Y
selenium	3/3	0.200	0.41	0.28	Y	7/9	0.17	0.45	0.23	Y
sodium	3/3	997	1,370	1,136	N [c]	9/9	912	1,370	1,118	N [c]
zinc	3/3	12	21	16	Y	9/9	12	51	27	Y

Notes:

[a] Number of detects per total number of analyses.

[b] Average calculated using 1/2 the SQL.

[c] Essential nutrients, with the exception of iron, were eliminated as fish COPCs.

ND = Not detected.

TABLE 7-24
SUMMARY OF CHEMICALS THAT EXCEED REGIONAL (a) OR NATIONAL (b) DATA BY SPECIES
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	COLD SPRING BROOK POND FISH [c]							
	PUMPKINSEED		BULLHEAD		CHAIN PICKEREL		ALL FISH	
	Regional	National	Regional	National	Regional	National	Regional	National
PESTICIDES/PCBs								
aroclor-1254								
DDD								
DDE	X		X		X		X	
INORGANICS								
aluminum								
arsenic								
barium								
cadmium								
chromium								
cobalt								
copper								
iron	X		X		X		X	
lead								
manganese	X		X		X		X	
mercury		X				X		X
nickel								
selenium								
thallium								
zinc	X		X		X	X	X	X
TOTAL EXCEEDANCES	5		4		6		6	

Notes:

[a] PSP average concentrations exceeding regional average concentrations (Massachusetts Division of Water Pollution Control [MADWPC], 1988a; 1988b, 1989; 1990; 1991).

[b] PSP maximum concentrations exceeding national maximum or 85th percentile concentrations (United States Fish and Wildlife Service [USFWS], 1990a; 1990b).

[c] Comparison of fish tissue concentrations to regional and national data presented in Appendix N, Tables N-11 through N-14.

TABLE 7-25
PLANT COMMUNITIES IDENTIFIED IN THE GENERAL
VICINITY OF THE COLD SPRING BROOK LANDFILL (a)

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

	COVER TYPE	DOMINANT SPECIES (b)
1.	Scotch Pine Plantation	Scotch pine
2.	Old Field	White pine, Sweetfern, Spotted knapweed, Panic grass
3.	Aspen--Birch, Early Successional Forest	Quaking aspen, Paper birch, Smooth sumac, Smooth alder Panic grass
4.	Aspen Early Successional Forest	Eastern cottonwood, Quaking aspen, Big-tooth aspen, Sweetfern, Poison ivy, Rough goldenrod
5.	Sumac Thicket	Red pine, Staghorn sumac, Black raspberry, Panic grass
6.	Red Pine Plantation	Red pine, Autumn olive, Spotted knapweed
7.	Alder--Buttonbush Wetland Forest	Smooth alder, Buttonbush, Sedge, Enchanter's nightshade
8.	Peat Wetland	Red maple, Paper birch, Meadowsweet, Bristly dewberry Marsh fern
9.	Swamp Loosestrife Peninsula	Swamp loosestrife, Marsh fern
10.	White Pine--Cinnamon Fern Forested Wetland	White pine, Red maple, American hazelnut, Cinnamon fern
11.	Red Maple Peninsula	Red maple, Paper birch, Silky dogwood, Marsh fern, Swamp loosestrife
12.	Red Maple Island Area	Red maple, smooth alder, Bristly dewberry, Marsh fern Swamp loosestrife
13.	Emergent Marsh	Silky dogwood, Broad-leaf cattail, Soft rush
14.	Red Maple--Highbush Blueberry Wetland	Red maple, Highbush blueberry, Smooth alder, Cinnamon fern, Marsh fern
15.	Red Maple--White Pine Forested Wetland	Red maple, White pine, American elm, Witch hazel, Silky dogwood, Rice cutgrass, Spotted jewelweed, Cinnamon fern

TABLE 7-25
PLANT COMMUNITIES IDENTIFIED IN THE GENERAL
VICINITY OF THE COLD SPRING BROOK LANDFILL (a)

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

	COVER TYPE	DOMINANT SPECIES (b)
16.	White Pine Forest	White pine, Red maple, American hazelnut, Canada mayflower, Ground cedar
17.	Scarlet Oak Forest	Scarlet oak, White pine, American hazelnut, Ground cedar Canada mayflower
18.	Mixed Oak Forest Forest	Scarlet oak, White oak, Sheep laurel, Ground pine
19.	White Pine--Red Maple Forest	White pine, Red maple, Cinnamon fern
20.	Mixed Oak--White Pine Forest	Scarlet oak, White oak, White pine, American chestnut Witch hazel, Dwarf blueberry, Wintergreen
21.	Aspen Early Successional Forest	Quaking aspen, Big-tooth aspen, Sweet fern, Early goldenrod
22.	Paper Birch--White Pine Shrubland	Paper birch, White pine, Dwarf blueberry, Moss
23.	Scarlet Oak--Birch Early Successional Forest	Scarlet oak, Paper birch, Gray birch, Red maple, White pine, Dwarf blueberry, Wintergreen
24.	Scarlet Oak Forest	Scarlet oak, White pine, Black huckleberry, Indian pipe, Pink ladyslipper

Notes:
(a) Source: E&E (1993)
(b) Dominant species listed only

TABLE 7-26
CHECKLIST OF FISHES COLLECTED AT COLD SPRING BROOK POND (CSBP)

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

CHORDATA	
OSTEICHTHYES	
ANGUILLIFORMES	
Anguillidae	
Anguilla rostrata (Lesueur)	American Eel
SALMONIFORMES	
Esocidae	
Esox niger (Lesueur)	Chain Pickerel
CYPRINIFORMES	
Cyprinidae	
Notemigonus crysoleucas (Mitchill)	Golden Shiner
SILURIFORMES	
Ictaluridae	
Ictalurus natalis (Lesueur)	Yellow Bullhead
PERCIFORMES	
Centrarchidae	
Lepomis gibbosus (Linnaeus)	Pumpkinseed
Pomoxis nigromaculatus (Lesueur)	Black Crappie

TABLE 7-27
SUMMARY OF SEDIMENT CHEMISTRY DATA FROM MACROINVERTEBRATE SAMPLING STATIONS
COLD SPRING BROOK POND AND NEW CRANBERRY POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	FREQUENCY OF DETECTION [a]	COLD SPRING BROOK POND CONCENTRATION [b]		FREQUENCY OF DETECTION [a]	CRANBERRY POND CONCENTRATION [b]	
		AVERAGE	MAXIMUM		AVERAGE	MAXIMUM
ORGANICS (ug/kg)						
benzo(a)pyrene	1/3	7	20	0/3	ND	ND
nitroglycerine	1/3	5.1	11.3	0/3	ND	ND
total organic carbon	3/3	167,887	471,000	3/3	60,113	100,000
DDD	2/3	0.061	0.15	1/3	0.14	0.295
DDE	2/3	0.017	0.034	1/3	0.059	0.13
DDT	2/3	0.024	0.061	1/3	0.03	0.07
INORGANICS (ug/kg)						
aluminum	3/3	5,537	8,110	3/3	8,427	11,100
arsenic	3/3	102	280	3/3	8.1	13.8
barium	3/3	41	73	3/3	34	57
chromium	3/3	26.7	49	1/3	4.02	8.9
cobalt	1/3	2.57	6.3	1/3	1.1	3.1
copper	1/3	2.83	7.5	3/3	7.1	13.9
iron	3/3	7,580	10,600	3/3	5,465	7,140
lead	3/3	10.2	11.6	3/3	42.1	97
manganese	3/3	477	1020	3/3	61.2	109
nickel	2/3	9.17	21.7	2/3	3.72	5.2
selenium	1/3	2.01	5.8	0/3	ND	ND
silver	1/3	0.454	0.773	0/3	ND	ND
vanadium	2/3	7.15	14	3/3	14.6	24.5
zinc	2/3	21	39.6	3/3	31.2	55

Notes:
ND = Not Detected.
[a] Frequency of detection represents the number of detects per total number of samples.
[b] 1/2 the SQL was used for non-detected values for calculation of averages.

TABLE 7-28
SURFACE WATER REFERENCE TOXICITY VALUES
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	USEPA AMBIENT WATER QUALITY CRITERIA (e) (µg/l)		TOXICITY VALUES (f) (µg/l)	
	Chronic	Acute	Chronic	Acute
INORGANICS				
arsenic (a)	190	360		
barium (b)	NA	NA	200	2,000
chromium (c)	88	740		
copper (c)	4.8	6.6		
iron	1,000	10,000		
manganese (d)	NA	NA	1,000	10,000
silver	0.12	0.92		
zinc (c)	44	48		

Notes:
[a] Values shown are for trivalent arsenic (AsIII).
[b] Lowest end of range of concentrations lethal to aquatic invertebrates and fish (NAS, 1972) with a safety factor of 0.2 applied.
[c] AWQC are dependent upon water hardness. The average Cold Spring Brook hardness (35 mg/l $CaCO_3$) was used.
[d] Value reported by McKee and Wolf (1963 in USEPA, 1976) and Davies and Goettl (in Lewis et al., 1979) which is considered protective of freshwater species.
[e] USEPA (1986)
[f] Other reference toxicity values are presented only for those chemicals for which AWQC are not available.

TABLE 7–29
SEDIMENT QUALITY CRITERIA AND GUIDELINES
COLD SPRING BROOK POND

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	USEPA [a] SQC (µg/g)	NOAA [b] ER–L (µg/g)	NOAA [b] ER–M (µg/g)	NYSDEC [c] (µg/g)	ONTARIO LOWEST EFFECT LEVEL [d] (µg/g)	USEPA REGION V [e] (µg/g)
ORGANICS						
anthracene	NA	0.085	0.96	NA	NA	NA
bis (2–ethylhexyl) phthalate	NA	NA	NA	21.9	NA	NA
benzo(a)anthracene	241	0.23	1.6	NA	NA	NA
benzo(a)pyrene	194.5	0.4	2.5	NA	NA	NA
benzo(b)fluoranthene	194.5 [f]	NA	NA	NA	NA	NA
benzo(k)fluoranthene	194.5 [f]	NA	NA	NA	NA	NA
chrysene	194.5 [f]	0.4	2.8	NA	NA	NA
dibenzofuran	NA	NA	NA	NA	NA	NA
fluoranthene	344.6	0.6	3.6	NA	NA	NA
phenanthrene	25.4	0.225	1.38	25.4	NA	NA
pyrene	239.9	0.35	2.2	NA	NA	NA
DDD	0.152 [g]	0.002	0.02	0.152	0.008	NA
DDE	0.152 [g]	0.002	0.015	0.152	0.005	NA
DDT	0.152	0.001	0.007	0.152	0.008	NA
INORGANICS						
aluminum	NA	NA	NA	NA	NA	NA
arsenic	NA	33	85	5	6	3
barium	NA	NA	NA	NA	NA	20
beryllium	NA	NA	NA	NA	NA	NA
chromium	NA	80	145	26	26	25
cobalt	NA	NA	NA	NA	50	NA
copper	NA	70	390	19	16	25
iron	NA	NA	NA	24,000	20,000	17,000
lead	NA	35	110	27	31	40
manganese	NA	NA	NA	428	460	300
mercury	NA	0.15	1.3	0.11	0.2	>1
nickel	NA	30	50	22	16	20
selenium	NA	NA	NA	NA	NA	NA
silver	NA	1	2.2	NA	0.5	NA
vanadium	NA	NA	NA	NA	NA	NA
zinc	NA	120	270	85	120	90

Notes:
[a] Organic carbon–normalized mean values from USEPA (1988) Interim Sediment Quality Criteria (SQC), using 18.3% total organic carbon in Cold Spring Brook Pond sediments.
[b] Effects Range–Low (ER–L) and Effects Range–Medium (ER–M) values from Long and Morgan (1990).
[c] New York State Department of Environmental Conservation ([NYSDEC], 1989). Organics normalized to 18.3% total organic carbon in sediment.
[d] Values are Lowest Effect Level reported in Persaud, et al. (1992).
[e] From USEPA (1977) Region V Sediment Classification System. Levels above those listed are considered moderately polluted, levels below are considered non–polluted. Lower limits were not established for mercury. Value listed represents heavily polluted sediment.
[f] Guideline for benzo(a)pyrene.
[g] Guideline for DDT.
NA = Not Available.

TABLE 7-30
SUMMARY OF EXTERNAL EXAMINATIONS OF SELECTED FISH IN COLD SPRING BROOK POND (CSBP), OCTOBER 1992. [A]

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

SPECIES	NUMBER EXAMINED	FRAYED FINS	TUMORS/ LESIONS	OTHER	REMARKS (FOR OTHER)
Pumpkinseed	17	0	0	1	1-frayed opercle
Golden Shiner	56	0	0	2	1-missing part of caudal; 1-bruise near anal fin

Notes:

[a] Fish captured in nets when the fin fraying was likely caused by the nets were not included in this tabulation.

TABLE 7-31
AQUATIC RECEPTOR RISK CHARACTERIZATION
COLD SPRING BROOK POND: SURFACE WATER

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	AVERAGE EXPOSURE			REASONABLE MAXIMUM EXPOSURE (RME)		
	Average (ug/l)	Chronic Criteria and Toxicity Values [a] (ug/l)	Hazard Quotient [b] (unitless)	Maximum (ug/l)	Acute Criteria and Toxicity Values [a] (ug/l)	Hazard Quotient [b] (unitless)
INORGANICS						
arsenic	7.7	190	4.05E-02	17.7	360	4.92E-02
barium	10.7	200	5.35E-02	13.4	2000	6.70E-03
chromium	2.7	88	3.10E-02	4.76	740	6.43E-03
copper	4.4	4.8	9.25E-01	6.75	6.6	1.02E+00
iron	1,560	1,000	1.56E+00	3,200	10,000	3.20E-01
manganese	151	1,000	1.51E-01	400	10,000	4.00E-02
silver	0.2	0.12	1.78E+00	0.708	0.92	7.70E-01
zinc	21.8	44	4.95E-01	86.3	48	1.80E+00
	TOTAL AVERAGE HAZARD INDEX [c]		5.03E+00	TOTAL RME HAZARD INDEX [c]		4.01E+00

Notes:

[a] Criteria from Table 7-28, chosen as described in Section 7.2.3.4.

[b] Hazard Quotient is calculated by dividing analyte concentration by surface water criterion/toxicity value.

[c] Hazard Index is the sum of all hazard quotients.

NA = Not Available

Shaded values represent a hazard index greater than one

TABLE 7-32
AQUATIC RECEPTOR RISK CHARACTERIZATION
COLD SPRING BROOK POND: SEDIMENT

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

ANALYTE	AVERAGE EXPOSURE			REASONABLE MAXIMUM EXPOSURE (RME)		
	Average (ug/g)	Sediment Quality Criteria and Guidance Values [a] (ug/g)	Hazard Quotient [b] (unitless)	Maximum (ug/g)	Sediment Quality Criteria and Guidance Values [a] (ug/g)	Hazard Quotient [b] (unitless)
ORGANICS						
anthracene	0.27	0.085	3.18E+00	3	0.085	3.53E+01
benzo(a)anthracene	0.51	241	2.12E-03	4	241	1.66E-02
benzo(a)pyrene	1.1	194.5	5.66E-03	6	194.5	3.08E-02
benzo(b)fluoranthene	0.64	194.5	3.29E-03	5	194.5	2.57E-02
benzo(k)fluoranthene	0.9	194.5	4.63E-03	10	194.5	5.14E-02
bis(2-ethylhexyl)phthalate	1.4	21.9	6.39E-02	2	21.9	9.13E-02
chrysene	0.63	194.5	3.24E-03	8	194.5	4.11E-02
dibenzofuran	0.15	NA	NA	0.61	NA	NA
fluoranthene	1.6	344.6	4.64E-03	10	344.6	2.90E-02
phenanthrene	0.77	25.4	3.03E-02	6	25.4	2.36E-01
pyrene	2.2	239.9	9.17E-03	20	239.9	8.34E-02
DDD	0.5	0.152	3.29E+00	6.2	0.152	4.08E+01
DDE	0.09	0.152	5.92E-01	0.72	0.152	4.74E+00
DDT	0.64	0.152	4.21E+00	15	0.152	9.87E+01
INORGANICS						
aluminum	6,109	NA	NA	17,000	NA	NA
silver	0.65	1	6.50E-01	6.35	1	6.35E+00
arsenic	78	33	2.36E+00	390	33	1.18E+01
barium	36.8	20	1.84E+00	115	20	5.75E+00
beryllium	0.19	NA	NA	0.41	NA	NA
cobalt	3.38	50	6.76E-02	19.6	50	3.92E-01
chromium	15.2	80	1.90E-01	64.8	80	8.10E-01
copper	8.5	70	1.21E-01	42.9	70	6.13E-01
iron	15,233	24,000	6.35E-01	45,000	24,000	1.88E+00
lead	69.4	35	1.98E+00	570	35	1.63E+01
manganese	634	428	1.48E+00	3,000	428	7.01E+00
mercury	0.077	0.15	5.13E-01	0.72	0.15	4.80E+00
nickel	10.8	30	3.60E-01	54.3	30	1.81E+00
selenium	1.96	NA	NA	5.77	NA	NA
vanadium	12.1	NA	NA	48.6	NA	NA
zinc	82.3	120	6.86E-01	690	120	5.75E+00
	TOTAL AVERAGE HAZARD INDEX [c]		1.91E+01	TOTAL RME HAZARD INDEX [c]		2.08E+02

Notes:
[a] Criteria from Table 7-29, chosen as described in Section 7.2.3.4.
[b] Hazard Quotient is calculated by dividing analyte concentration by sediment quality criterion/guidance value.
[c] Hazard Index is the sum of all hazard quotients.
NA = Not Available
Shaded values represent a hazard index greater than one

TABLE 7-33
SUMMARY OF ECOLOGICAL RISK ASSESSMENT FOR SEMI-AQUATIC RECEPTORS
COLD SPRING BROOK LANDFILL

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A SITES
FORT DEVENS, MA

INDICATOR SPECIES	HAZARD INDICES		PRIMARY CONTRIBUTORS TO RISK [c]
	RME [a]	AVERAGE [b]	
Mallard Duck	1.4E+00	2.2E-01	
Great Blue Heron	6.5E-02	8.6E-03	
Green Frog	2.4E+00	4.7E-01	arsenic
Painted Turtle	4.9E-01	9.8E-02	
Muskrat	2.8E-01	5.5E-02	
Mink	2.8E-01	5.0E-02	
Raccoon	4.0E-03	7.8E-04	

Notes:

[a] HIs derived under reasonable maximum exposure assumptions (see Section 7.2.3.5); calculations presented in Table R-12 in Appendix R.

[b] HIs derived under average exposure assumptions (see Section 7.2.3.5); calculations presented in Table R-10 in Appendix R.

[c] Analytes with calculated HQs in excess of 0.9 for either the RME or average exposure scenarios.

TABLE 7-34
POTENTIAL SOURCES OF UNCERTAINTY IN ECOLOGICAL RISK ASSESSMENT

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A STUDY AREAS
FORT DEVENS, MA

POTENTIAL SOURCE	EFFECT ON RISK ESTIMATION	JUSTIFICATION
Degradation of chemicals not considered	Overestimate	Risk estimates are based on a one-time sampling event. Chemical concentrations will tend to decrease over time from degradation.
Nutrient Concentrations	Unknown	Not all essential nutrients (i.e., iron) were evaluated in all media.
Extrapolation between animal species	Unknown	Animals differ in absorption, metabolism, distribution, and excretion of chemicals. The magnitude and direction of the difference will vary with each chemical.
Fish population sample	Unknown	Fish collected for tissue analysis, qualitative community study, and pathological evaluation represent a small percentage of the fish community and a one-time sample, not a survey of all fish.
Use of surface water data	Overestimate	Use of total, rather than dissolved, surface water data overestimates risk because bioavailabilty is not accounted for.
MADWPC fish database	Unknown	MADWPC fish tissue database represents a limited data set compiled from several different studies. Actual tissue burden in MA ponds may differ.
Only gross pathological abnormalities in fish were identified	Underestimate	Pathological evaluation of fish identified only gross abnormalities. Some sublethal physiological effects may not have been identified.

(continued)

TABLE 7-34
POTENTIAL SOURCES OF UNCERTAINTY IN ECOLOGICAL RISK ASSESSMENT

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A STUDY AREAS
FORT DEVENS, MA

POTENTIAL SOURCE	EFFECT ON RISK ESTIMATION	JUSTIFICATION
New Cranberry Pond used as reference habitat for macroinvertebrate study	Unknown	New Cranberry Pond may not be an ideal reference for macroinvertebrate study.
Macroinvertebrate sampling methodology	Unknown	More motile macroinvertebrate organisms may have avoided capture. Smaller organisms may have passed through the 600 micron mesh dip net used to conduct the study.
Macroinvertebrate biotic indices	Unknown	The majority of biotic indices for macroinvertebrates were developed for organic compounds. The Fort Devens 1A COPCs tend to be inorganics.
Not all pathways evaluated for semi-terrestrial receptors	Underestimate	Neither dermal absorption nor inhalation pathway was evaluated for semi-terrestrial receptors.
Surface water AWQC	Unknown	Because available hardness data is outside of the AWQC alogorithm range, an assumption has been made that AWQC are based on a hardness of 50 mg/l $CaCO_3$.
Conservative RTVs	Overestimate	Some benchmark RTVs (e.g., the SQC for 4,4'-DDT) may be too conservative for use at Fort Devens.
Food chain assumed to occur at site	Unknown	Significance of degree of trophic transfer modeled at the sites is unknown.

(continued)

TABLE 7-34
POTENTIAL SOURCES OF UNCERTAINTY IN ECOLOGICAL RISK ASSESSMENT

REMEDIAL INVESTIGATION ADDENDUM REPORT
FEASIBILITY STUDY FOR GROUP 1A STUDY AREAS
FORT DEVENS, MA

POTENTIAL SOURCE	EFFECT ON RISK ESTIMATION	JUSTIFICATION
BAFs are the primary factor used for fish tissue burden estimation	Unknown	BAFs used to evaluate risk to semi-terrestrial receptors is an artificial modeling tool. Other physical and biological factors may contribute to tissue burden in fish (e.g., pond trophic level and fish lipid concentrations).
BAF values	Unknown	Considerable uncertainty is associated with the use of BAFs. BAF values may range over the course of several orders of magnitude among taxa and sites.
Food chain model exposure parameter assumptions	Unknown	Some exposure parameters are from the literature, some are assumed or estimated. Efforts were made to select exposure parameters representative of a variety of species or feeding guilds, so that exposure estimates would be representative of more than a single species.
Assumption that receptor species will spend equal time at all habitats within home range	Unknown	Organisms will spend varying amounts of time in different habitats which would affect their exposures.
Uncertain occurrence of receptors at sites	Overestimate	Actual occurrence at the sites by receptors considered in the food chain models is uncertain (i.e., the osprey is a site transient, nota resident).

(continued)

Table 7-34
Potential Sources of Uncertainty in Ecological Risk Assessment

Remedial Investigation Addendum Report
Feasibility Study for Group 1A Study Areas
Fort Devens, MA

Potential Source	Effect on Risk Estimation	Justification
Consumption of contaminated prey	Unknown	Toxicity to prey receptors may result in sickness or mortality. Fewer prey items would be available for predators. Predators may stop foraging in areas with reduced prey populations, discriminate against, or conversely, select contaminated prey.
Multiple conservative assumptions	Overestimate	Cumulative impact of multiple conservative assumptions, yields high risk to ecological receptors.
Risk evaluated for individual receptors only	Overestimate	Effects on individual organisms may occur with little population or community level effects.
Summation of effects (HIs)	Unknown	The assumption that effects are additive ignores potential synergistic or antagonistic effects. Assumes similarity in mechanism of action, which is not the case for many substances. Compounds may induce toxic effects in different organs or systems.

8.0 SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Supplemental RI activities were conducted by ABB-ES personnel at Fort Devens Group 1A sites to fill data gaps identified in the RI report (E&E, 1993). Results from supplemental RI activities were used to update the baseline risk assessment.

8.1 SUMMARY

Environmental sampling was performed at Shepley's Hill Landfill, Cold Spring Brook Landfill and several adjacent or related areas to better define the nature and extent of site contamination and further develop ABB-ES' and the Army's understanding of the Group 1A sites. Supplemental RI activities included the following:

Shepley's Hill Landfill

- Installation of three overburden and two bedrock groundwater monitoring wells
- Collection and analysis of groundwater samples from 27 monitoring wells
- Performing a seismic refraction study to characterize the bedrock surface
- Collection and analysis of sediment samples from 28 locations and several depths in Plow Shop Pond
- Collection of surface water and shallow sediment samples from five locations along the western end of Grove Pond
- Collection and analysis of shallow groundwater and soil samples from four locations in the wooded wetland area north of Shepley's Hill Landfill

- Collection and semiquantitative evaluation of macroinvertebrate samples at three locations in Plow Shop Pond.
- Fishery evaluation and fish tissue sampling and analysis in Plow Shop Pond
- Conducting a Wetland Functional Assessment (WET 2)

Cold Spring Brook Landfill

- Installation of three overburden groundwater monitoring wells
- Collection and analysis of groundwater samples from 10 new and existing monitoring wells and Patton Well
- Collection and analysis of sediment samples from 13 locations and several depths in Cold Spring Brook Pond
- Collection and analysis of surface water and sediment samples from three suspected seep locations
- Collection and analysis of shallow groundwater and soil samples from three locations within or adjacent to the Magazine Area
- Collection and semiquantitative evaluation of macroinvertebrate samples at three location in Cold Spring Brook Pond
- Fishery evaluation and fish tissue sampling and analyses in Cold Spring Brook Pond
- Conducting a Wetland Functional Assessment (WET 2)

Data obtained from field activities was used to update the baseline risk assessment for Shepley's Hill Landfill and Cold Spring Brook Landfill. A PRE was conducted for the Nonacoicus Brook Wetland area just north of Shepley's Hill Landfill.

8.2 Conclusions

The following conclusions are based on interpretation of RI and supplemental RI data and the updated baseline risk assessment.

Shepley's Hill Landfill

- Downgradient groundwater at Shepley's Hill Landfill discharges east, toward Plow Shop Pond and north, toward Nonacoicus Brook.

- Downgradient groundwater at Shepley's Hill Landfill is contaminated with nine VOCs which are present at low concentrations. These VOCs are acetone; benzene; chloroethane; dichlorobenzenes; 1,1-dichloroethane; 1,2-dichloroethane, 1,2-dichloroethylenes; 1,2-dichloropropane; and toluene. Dichlorobenzenes (non-specific) were reported at the highest concentration (11 μg/L). The compound 1,2-dichloroethane was found at 9.9 μg/L and was the only VOC that exceeded its MCL. The groundwater is also contaminated with several inorganics of which aluminum, arsenic, and manganese are the most significant.

- With the exception of arsenic and iron, high concentrations of inorganics are typically associated with high TSS concentrations in the groundwater sample.

- Plow Shop Pond sediments are contaminated with several inorganics including arsenic, barium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. Of these, Shepley's Hill Landfill is interpreted to be the major contributor of iron, manganese, barium, and nickel. The landfill is also considered a source of arsenic contamination. Inflow from Grove Pond is interpreted as the major source of arsenic, copper, chromium, lead, mercury, and zinc.

- The macroinvertebrate community in Plow Shop Pond is slightly impaired and has a lower diversity and higher percentage of pollution tolerant species than the South Post reference pond. These differences are most apparent in the vicinity of the landfill.

- The fishery of Plow Shop Pond appears typical of a southern New England warm water pond. Individual fish appear healthy.

- The ecological risk assessment suggests that contaminants in Plow Shop sediment may pose a risk to aquatic and semiaquatic receptors. The primary risk contributor is mercury, followed by chromium, arsenic, and manganese.

- Risk calculations made during the human health risk evaluation suggest that a recreational fisherman or family member who consumes fish from Plow Shop Pond may experience cancer risks of $3x10^{-6}$ to $4x10^{-4}$, due primarily to arsenic, and noncancer risks (HQs range from 2 to 7) due primarily to mercury. Direct contact with sediment by adolescents was estimated to present cancer risks of $2x10^{-5}$ to $6x10^{-4}$, due primarily to arsenic. Because the calculations may overestimate risk as a result of uncertainty associated with arsenic, the application of a downward modifying factor of 10 may be appropriate.

  Application of the risk modification factor for arsenic results in cancer risks that are within the Superfund target risk range of $1x10^{-6}$ to $1x10^{-4}$, and the conclusion that the major health risk associated with Plow Shop Pond sediment and fish is attributable to mercury, a contaminant not attributed to Shepley's Hill Landfill. Concentrations of mercury in bullhead and bass fillets exceed the FDA action level of 1 ppm.

  The human health risk evaluation indicates that two organic analytes in groundwater, 1,2-dichloroethane and dichlorobenzenes present cancer risks of $6x10^{-6}$ and $3x10^{-6}$, respectively, that are within the Superfund target risk range. Arsenic in groundwater presents a cancer risk range (unmodified to account for uncertainty associated with arsenic) of $8x10^{-5}$ to $2x10^{-3}$. Application of the modifying risk factor results in a risk range due to arsenic of $8x10^{-6}$ to $2x10^{-4}$. Hazard quotients for manganese and arsenic both exceeded one.

Cold Spring Brook Landfill

- Cold Spring Brook Landfill is located over a historical groundwater discharge area. However, pumping at Patton Well located west of the landfill may influence groundwater flow at the western end of the landfill.

- Cold Spring Brook Landfill is not contaminating groundwater or affecting groundwater quality at Patton Well.

- Cold Spring Brook Pond sediments are contaminated with PAHs, arsenic, and several other inorganics. Contamination hot spots exist at two locations:

  1) near the pond outlet; and

  2) at a small cove on the southern shore of the landfill near monitoring wells CSB-5 and CSM-93-01

- Explosives are not migrating from the Magazine Area to Cold Spring Brook Pond in shallow groundwater or sediments.

- The macroinvertebrate community in Cold Spring Brook Pond may be slightly impaired when compared to a South Post reference pond, but is less impacted than the macroinvertebrate community of Plow Shop Pond.

- The fishery of Cold Spring Brook Pond is typical of a southern New England warm water fish community. Individual fish appear healthy.

- The ecological risk assessment suggests that COPCs at Cold Spring Brook Pond are not resulting in adverse ecological risks to semiaquatic receptors. Although low levels of risks are predicted, it is unlikely that these risks are present throughout the pond. Limited evidence exists indicating that low levels of risk to aquatic receptors may occur in portions of the pond directly adjacent to the landfill.

- The human health risk evaluation indicates that risks to a recreational fisherman or family member who consumes fish caught in Cold Spring Brook Pond fall within the Superfund target risk range. The risks associated with direct sediment contact are also within the Superfund target risk range.

  The risks associated with surface soil contact range from below the Superfund target risk range under current exposure scenarios to $4x10^{-5}$, within the target risk range, under assumed future conditions.

  Risk calculations made during the risk evaluation suggest that arsenic in unfiltered groundwater and bis(2-ethylhexyl)phthalate present cancer risks exceeding the USEPA point of departure. In addition, the HQ for manganese ranged from 4 to 10. The calculations may overestimate risks for each of these chemicals. In the case of arsenic, calculations based on filtered groundwater data or after application of a downward modifying factor of 10 both result in estimated cancer risks within or below the target risk range. The primary MCL for bis(2-ethylhexyl)phthalate of 6 μg/L was exceeded only by its maximum detected concentration of 14 μg/L; the average concentration of 4 μg/L was below the MCL. In addition, this SVOC is expected to sorb to particulate matter and not to be in a dissolved, mobile state. Finally, noncancer risks associated with manganese in drinking water may be overestimated. Consideration of these factors leads to the conclusion that exposure to groundwater downgradient of Cold Spring Brook Landfill will not result in unacceptable risk.

<u>Nonacoicus Brook Wetland</u>

- Public health and ecological PREs conducted for detected contaminants indicate some exceedances of public health standards or guidelines for soil and groundwater and one exceedance of an ecological PCL. However, the exceedances are based on comparisons to conservative standards and are not considered to represent significant public health or ecological risk.

Magazine Area

- Concentrations of PAHs and inorganics measured in soil samples collected within the Magazine Area were below reportable concentrations listed in the MCP. Available data do not suggest that the Magazine Area is a source of downstream contamination.

8.3 RECOMMENDATIONS

Based on the results and interpretation of the supplemental RI and the updated baseline risk assessment, ABB-ES recommends the following actions:

- Perform a FS to evaluate alternatives to reduce potential human health risks associated with potential future exposure to groundwater at Shepley's Hill Landfill.

- Perform a FS to evaluate alternatives to reduce potential ecological risks associated with exposure to sediment hotspots at Cold Spring Brook Landfill.

- Perform a separate FS to evaluate alternatives to reduce potential human health and ecological risks associated with exposure to contaminated fish and sediments in Plow Shop Pond. This FS would be performed following resolution of issues concerning contaminant distribution and concentrations in Grove Pond, and the potential for Grove Pond to be a continuing source of contamination to Plow Shop Pond.

ABB-ES	ABB Environmental Services, Inc.
AC	alternating current
AEC	U.S. Army Environmental Center
ASL	above sea level
ASP	Ammunition Supply Point
AOC	Area of Contamination
ARARs	Applicable or Relevant and Appropriate Requirements
AWQC	Ambient Water Quality Criteria
BAF	bioaccumulation factor
BCF	Bioconcentration Factor
bgs	below ground surface
BRAC	Base Closure and Realignment Act
BW	Body Weight
CAA	Clean Air Act
CCC	Civilian Conservation Corps
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
CMC	Criterion Maximum Concentration
CMR	Code of Massachusetts Regulations
cm/sec	centimeters per second
CMTC	Civilian Military Training Corps
COC	chain-of-custody
COPC	Contaminant of Potential Concern
COR	Contracting Officer's Representative
CRDL	Contract Required Detection Limit
CRL	Certified Reporting Limit
CWA	Clean Water Act
DOI	U.S. Department of the Interior
DQO	Data Quality Objective
DRMO	Defense Reutilization and Marketing Office
ECD	Electron Capture Detector
E&E	Ecology and Environment, Inc.

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ED	Exposure Duration
EDM	Electronic Distance Meter
EPC	Exposure Point Concentration
EPT	Ephemeroptera, Plecoptera, Trichoptera
EPT/C	Ratio of Ephemeroptera, Plecoptera, and Trichoptera to Chironomidae
ERA	Ecological Risk Assessment
ER-L	Effects Range-Low
ER-M	Effects Range-Medium
ESE	Environmental Science & Engineering, Inc.
FAV	Final Acute Value
FBI	family biotic index
FCV	Final Chronic Value
FDA	U.S. Food and Drug Administration
FEMA	Federal Emergency Management Agency
FESA	Federal Endangered Species Act
FID	Flame Ionization Detector
FPV	Final Plant Value
FRV	Final Residue Value
FS	Feasibility Study
FSP	Field Sampling Plan
GC	Gas Chromatograph
gpm	gallons per minute
HA	Health Advisory
HASP	Health and Safety Plan
HEAST	Health Effects Assessment Summary Tables
HI	Hazard Index
HQ	Hazard Quotient
HSA	Hollow Stem Auger
IAG	Interagency Agreement
IBI	Index of Biological Integrity
IDW	Investigation Derived Waste
IR	Ingestion Rate

IRDMIS	Installation Restoration Database Management Information System
IRIS	Integrated Risk Information System
LD50	Lethal Dose 50
LDR	Land Disposal Restrictions
LOAEL	Lowest Observed Adverse Effects Level
MAAF	Moore Army Airfield
MADEP	Massachusetts Department of Environmental Protection
MADWPC	Massachusetts Division of Water Pollution Control
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDWS	Massachusetts Division of Water Supply
MEP	Master Environmental Plan
MESA	Massachusetts Endangered Species Act
mg/kg	milligrams per kilograms
mg/L	milligrams per liter
MHC	Massachusetts Historical Commission
mm	millimeters
MMCL	Massachusetts Maximum Contaminant Level
MNG	Massachusetts National Guard
MNHP	Massachusetts Natural Heritage Program
mph	miles per hour
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NCBMP	National Contaminant Biomonitoring Program
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NGVD	National Geodetic Vertical Datum
NIPDWS	National Interim Primary Drinking Water Standard
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effects Level
NPDES	National Pollutant Discharge Elimination System
NPDWS	National Primary Drinking Water Standard
NPL	National Priority List
NPR	Notice of Proposed Rulemaking
NWR	National Wildlife Refuge

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

NYSDEC	New York State Department of Environmental Conservation
ODW	(USEPA) Office of Drinking Water
OSHA	Occupational Safety and Health Administration
OSR	(Massachusetts) Office of Research and Standards Guideline
OSWER	USEPA Office of Solid Waste and Emergency Response
PAH	Polynuclear Aromatic Hydrocarbon
PAL	Project Analyte List
PCB	polychlorinated biphenyl
PCL	Protective Contaminant Level
PDE	Potential Dietary Exposure
PED	Potential Exposure Dose
PID	Photoionization Detector
POL	Petroleum Oil and Lubricants
POP	Project Operations Plan
PPDDD	2,2-bis(para-chlorophenyl)-1,1-dichloroethane
PPDDE	2,2-bis(para-chlorophenyl)-1,1-dichloroethene
PPDDT	2,2-bis(para-chlorophenyl)-1,1,1-trichloroethane
ppm	parts per million
PSI	Potomac Research, Inc.
PSP	Plow Shop Pond
PVC	polyvinyl chloride
QA	Quality Assurance
QAPjP	Quality Assurance Project Plan
QC	Quality Control
RA	Risk Assessment
RAF	Relative Absorption Factors
RAGS	Risk Assessment Guidance for Superfund
RAS	Routine Analytical Service
RBP	Rapid Bioassessment Protocol
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RfD	Reference Dose
RI	Remedial Investigation
RME	Reasonable Maximum Exposure

ROTC	Reserve Officer Training Corps
RTV	Reference Toxicity Value
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SCS	Soil Conservation Service
SDWA	Safe Drinking Water Act
SF	Slope Factor
SFF	Site Foraging Frequency
SMCLs	Secondary Maximum Contaminant Levels
SQL	Sample Quantitation Limit
SVOC	semivolatile organic compound
TAL	Target Analyte List
TBC	to be considered
TBD	Total Body Dose
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TOC	total organic carbon
TSCA	Toxic Substances Control Act
TSCR	Total Site Cancer Risks
TSD	Treatment, Storage, or Disposal
TSNCR	Total Site Noncancer Risks
TSS	total suspended solids
μg/g	micrograms per gram
μg/kg	micrograms per kilograms
μg/L	micrograms per liter
μg/ml	micrograms per milliliters
USAEHA	U.S. Army Environmental Hygiene Agency
USAR	U.S. Army Reserve
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Service

VOC	volatile organic compound
WET	Wetland Evaluation Technique
WPA	Works Progress Administration

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